1995 Research & Technology Report

Foreword

The National Aeronautics and Space Administration (NASA) has since its inception been a driving force in creating a more promising future. A major component of NASA's strategy for the future is found in the various programs and efforts that are administrated through NASA's Office of Equal Opportunity Programs. The future success of NASA's ability to push back the boundaries of space and science will be dependent on our ability to tap into the nation's vast resource of minority and disabled talent. In the past, academic institutions with large minority or disabled student populations and the minority/disabled students themselves have not participated in scientific and technical disciplines in numbers that reflect their capabilities or representation in America's population. It is NASA's intent to address this disparity by supporting educational opportunities in mathematical, scientific, and technical disciplines for minority and disabled students. Through these opportunities, NASA is building a resource of research infrastructure and individual talent that is available to broaden the agency's technical excellence. NASA has invested in a future that will be enhanced by America's diversity.

As a representative of NASA, I am pleased with the progress we have made thus far which is documented in this publication. Through our assistance, many of the nation's Historically Black Colleges and Universities, Hispanic-Serving Institutions, and Tribal Colleges have refocused their energy and commitment toward science, mathematics, and technology. A strong, self-sufficient minority university research community is one of the objectives we have targeted, and 1995 has seen much progress toward that goal. In sum, the faculty, students, and institutions that are the beneficiaries of our efforts have taken great strides in 1995 and offer even better successes in the years to come. By offering opportunity, NASA is fulfilling its obligation to create a future of excellence that is a product of America's greatest strength: diversity.

Dr. Yvonne Freeman
Associate Administrator
NASA Office of Equal Opportunity Programs

Preface

The programs administrated through NASA's Minority University Research and Education Division (MURED) have been cited by numerous publications and public figures as a major factor in stimulating the research interest in minority universities and increasing the production of minority students in science, mathematics, and engineering. This is a source of pride and accomplishment for MURED and serves as a motivating factor as we embark on our sixth year as NASA's vehicle to respond to Congressional and Presidential mandates to increase minority university and student participation and contribution to the agency's mission.

The minority groups that MURED assists are African Americans, Hispanics, Pacific Islanders, Native Americans, and the disabled.

As part of our strategy for the future we will continue to establish and improve the research infrastructure and capabilities of minority colleges and universities with efforts such as our University Research Centers in Minority Institutions (URC) program, Institutional Research Awards (IRA) program, and Faculty Awards for Research (FAR) program. We will also continue our focus on improving the educational pipeline with programs and assistance to the pre-college, college, graduate, post-graduate, and educator levels of our nation's schools.

NASA's minority-focused research and technology efforts have been in existence since the inception of the agency. With the full strength and commitment of MURED and the rest of NASA's Office of Equal Opportunity, the agency will continue to serve as a model for minority education and involvement in the federal sector.

Bettie White
Director
Minority University Research and Education Division
NASA Office of Equal Opportunity Programs

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Introduction
to the 1995 Reports and Abstracts

The 1995 reports and abstracts that follow are organized into three major groups, according to the MURED program area that supports them: University Research Centers at Minority Institutions (URCs), Institutional Research Awards for Minority Institutions (IRAs), and Faculty Awards for Research (FARs). The first two groupings are multidisciplinary, but the lattermost, FARs, is discipline-specific, and this is reflected in the organization of the reports in that section.

Abstracts are provided for new activities as yet unable to provide reports. Reports are provided for ongoing activities. The reporting institutions were provided guidelines for reporting, which they tailored to best suit the information to be conveyed.

University Research
Centers at Minority
Institutions (URC)

The University Research Centers (URC) at Minority Institutions Program seeks to achieve a broad-based, mainstream, competitive aerospace research capability among the nation's Historically Black Colleges and Universities (HBCUs) and Other Minority Universities (OMUs). The goal of the program is to:

• foster new science and technology concepts;

• expand the nation's base for aerospace research and development;

• develop mechanisms for increased participation by faculty and students of HBCUs and OMUs in mainstream research; and

• increase the production of underrepresented minorities with advanced degrees in NASA-related fields.

Seven universities received new URC cooperative agreement awards in 1995. Now in its fourth year, the program funds a total of fourteen research centers at OMUs and HBCUs. The awards are intended to enhance each university's competitive research capabilities, to expand the nation's base for aerospace research and development, and to increase participation of faculty and students from minority institutions in NASA-related research.

URCs perform scientific and/or engineering research relevant to the five NASA Strategic Enterprises described in the NASA Strategic Plan: Mission to Planet Earth; Aeronautics; Human Exploration and Development of Space; Scientific Research; and Space Technology.

Since minorities and those with disabilities are underrepresented at the graduate level in the scientific and technical disciplines related to NASA's mission, an increase in the number of underrepresented minorities and those with disabilities participating in this research, and thereby graduating in these fields, is an expected outcome of the NASA URC Program. Two hundred and sixty-one students were involved in URC research projects during the current funding year: 18 at the Ph.D. level; 106 at the M.S. level; and 137 at the B.S. level. Fifty-seven percent were male and 43% were female. Ninety percent were members of underrepresented ethnic minority groups: 83% at the Ph.D. level; 82% at the M.S. level; and 98% at the B.S. level.

1995 reports and abstracts for the fourteen programs follow.

"Establishment of the Center for Hydrology, Soil Climatology and Remote Sensing"
Principal Investigator: Dr. Tommy L. Coleman
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Date of Original Award: 1995

Abstract: We propose to establish a University Research Center (URC) for Hydrology, Soil Climatology, and Remote Sensing that will conduct research on hydrologic processes, with emphasis on remote sensing measurement and modeling of soil moisture. With a 20-year history of research in the application of remote sensing and geographic information system technology to a wide range of topics in hydrology, land surface processes, ecology, forestry, and agriculture, AAMU is in an excellent position to respond to the needs of the scientific community for a concentrated research program in hydrology and soil climatology. Hydrology is an integrated physical science and thus can serve as an organizational theme for many research and academic activities within the University. Through collaborative research, the Center will draw heavily on the expertise of the Physics Department at AAMU, the Global Hydrology and Climate Center (GHCC), and the Intergraph Corporation. GHCC consists of about 150 scientists and information specialists from NASA's Marshall Space Flight Center's (MSFC) Earth System Science Division and the Institute for Global Change Research and Education (IGCRE).

The initial research goal of this center will be to develop a measurement/modeling strategy from low-resolution satellite microwave data to derive soil moisture profile information and to determine its variability on a range of spatial scales. We propose a dynamic solution to soil moisture measurement by microwave radiometry that employs a physically based model of the relationship between brightness temperature (TB) and soil moisture coupled with hydrologic models. Since the spatial distribution of interferants can be determined by independent means and managed with geographic information system (GIS) technology, TB can be used as input to a model that solves the lateral inverse problem through a neural network transformation and disaggregates TB to the resolution of the hydrologic model. The hydrologic model, through solution of the vertical inverse problem, predicts the spatial distribution of soil moisture in the upper few centimeters of soil, and in turn computes the soil moisture profile (other variables being known). The soil moisture data can then be aggregated to the resolution of our regional-scale hydrologic model to periodically correct modeled soil moisture values with "real" values. These are important initial steps at the 10's-of-kilometers scale before we can measure soil moisture at larger scales, as called for in the Global Energy and Water Cycle Experiment (GEWEX) Continental-scale International Project (GCIP).

We will also pursue development of a precise, inexpensive, in-situ technique to measure soil moisture, which will facilitate Winfred Thomas Agricultural Research Station in testing out in-situ measurement and modeling strategies using ground-based microwave and thermal sensors. We will use existing data sets from the Little Washita River Basin of central Oklahoma and the Southern Great Plains to test and refine our distributed hydrologic models, and to implement the technology developed herein to compute regional-scale fluxes of water and energy.

"High Performance Polymers and Ceramics (HiPPAC) Research Center"
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Date of Original Award: 1992

Our research efforts are in three broad areas: electronic and non-linear optical (NLO) materials; polymer-based composites; and polymer-based ceramic composites. A brief description of our ongoing research programs follows.

Electronic and Non-linear
Optical MATERIALS
Researchers in the HiPPAC center are focusing on the preparation and characterization of non-linear optical (NLO), photorefractive, and piezoelectric polymers. Photorefractive materials are the principle candidates for applications that include high- density optical data storage and image processing. Piezoelectric polymers have applications to active suppression of vibration, health monitoring of composite structures, and joints in trussed systems.

We have utilized a wide range of chromophores to prepare new polymers for application to NLO, photorefractive, and piezoelectric materials. These chromophores include: fulvenes and benzofulvenes, donor-acceptor substituted imidazolyls, tricyanovinyl substituted indoline groups (as shown in figure 1 below), and donor-acceptor stilbenes. Several of the new materials that we have prepared have been shown to exhibit NLO behavior. For example, an approximately 0.2μm thickness of polymer 1 exhibits an r33 of 1pm/V at 633nm and 0.3 pm/V at 830nm upon poling with a 100V/μm field.

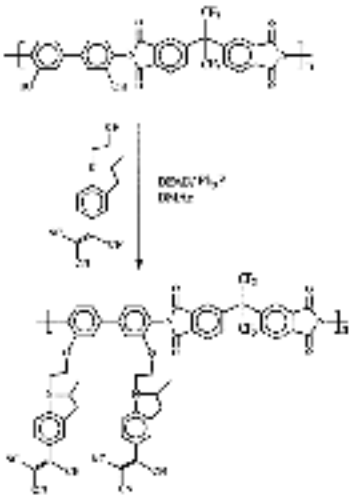

Figure 1. Tricyanovinyl Substituted Indoline Groups

Technology in this area is already being transferred to industry. The Center is working with industry via a Phase I Small Business Innovative Research (SBIR) award from the Air Force and a Phase I Small Business Technology Transfer (STTR) award from NASA.

Synthesis and characterization
of processable polymeric
precursors to polyimides
Thermoplastic resins such as polyimides offer many advantages over thermosets currently used in composite manufacturing. However, their inherently high melt viscosities are too high for practical composite manufacturing. To address this problem, we have developed methods to prepare precursor polyimides which can be easily fabricated into films and fibers, and subsequently converted to the more stable aromatic polyimides. Polyamic acid and precursor polyimide containing the bicyclo[2.2.2]oct-7-enering moiety have been prepared and characterized. The precursor polyimides are then converted to

the aromatic polyimide by pyrolysis as shown in Figure 2.

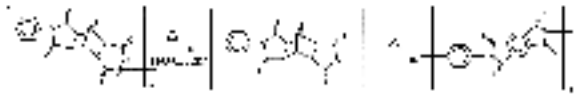

Figure 2. Precursor Polyimides converted to Aromatic Polyimide by Pyrolysis

The polyamic acid, I, is thermally stable up to 4150C under a nitrogen atmosphere. The precursor polyimide, II, is thermally stable up to 4600C under a nitrogen atmosphere. Polymer II is partially soluble in dimethyl sulfoxide, and soluble in concentrated sulfuric acid. Inherent viscosities were ca. 0.3g/dL at 300 C.

Additives to Enhance
Polyimide Processing

As another approach to increase the utility of polyimides for composite manufacturing, scientists working in the HiPPAC Center are also developing additives that improve the mechanical properties and processability of polyimides by lowering melt viscosity. Additives that we have prepared and tested are shown in Figure 3. Low concentrations of these additives in Ultem and LaRC TPI lead to only a small reduction in Tg and an increase in modulus (Antiplasticization).

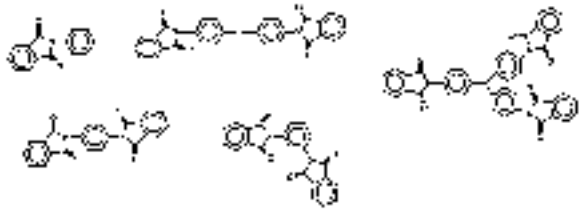

Figure 3. Additives for Enhanced Polyimide Processing

Fabrication, Engineering,
Property Characterization,
and Structural Design of High-Performance Composites

The aerospace industry needs lightweight structural materials possessing superior strength/weight and/or modulus/weight characteristics. The development of optimum lightweight structural materials requires a balance of properties and an efficient, low-cost processing methodology. Since future aircraft and weapons systems will remain in service for longer periods of time, the prediction of aging effects will be extremely important during the design and development of new materials. Hybrid titanium and polymeric matrix composite laminates, as depicted in Figure 4, have the potential of meeting this need.
The focus of this research is on the design and fabrication, processing and durability, testing and modeling for life-time prediction, and aging of hybrid titanium composite laminate systems. We are focusing on the fundamental materials issues at the microscale and interfaces, analytical modeling, thermomechanical fatigue testing and evaluation, and constitutive and damage modeling.

Hybrid laminates have been shown to exhibit orders of magnitude improvement in fatigue life on center-hole specimens tested at 205°C over monolithic Ti6-4. This class of materials has significant potential for application to lightweight, damage-tolerant structures operation at temperatures up to 230°C. These hybrid titanium composites have excellent lightning strike resistance and superior bolt-bearing load resistance compared to traditional PMC materials.

Figure 4. A typical unidirectional Titanium/Graphite/Polyimide composite laminate

We are studying the morphology, composition, and adhesive bonding in the interface region between the hybrid titanium and composite laminates using surface mapping infrared and Raman spectroscopes to allow macro scale (10-1 μm resolution) characterization; and Auger electron spectroscopy (AES) and scanning tunneling microscopy (STM) to allow micro scale (to the atomic scale) characterization. The metal oxide surface is being examined before and after surface treatment.

Figure 5. Hot Press Assembly for Analysis

MICROSCALE THERMAL ANALYSIS
Assemblies, analogous to a lap joint, such as shown in Figure 5, have been prepared in a hot press and then subjected to dynamic mechanical and thermomechanical analysis. This allows us to examine the combined effects of the polymer matrix composite (PMC), the primer-PMC, and primer-surface oxide interfaces.

Future work will include: accelerated aging test methods and durability, thermomechanical fatigue testing and evaluation, micromechanics modeling, constitutive and damage modeling, numerical micromechanical modeling, and analytical micromechanics modeling.

SOL-GEL BASED CERAMIC
MATERIALS PROCESSING
This research project utilizes sol-gel processing methods to prepare oxide ceramic fibers and powders, specifically mullite (3AI2O3-2SiO2), which is a material that retains its strength at high temperatures in oxidizing environments. The emphasis in this project is on developing a fundamental understanding of the physical, chemical, and structural evolutions occurring during the transformation from starting materials to the final dense mullite ceramic, either fiber or powder.

"NASA\FISK University Center For Photonic Materials and Devices"
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Report:
THE MISSION
As expressed in our original proposal, "the Center aims at updating and expanding Fisk research and development in photonic materials, consolidating them into a Center of Excellence able to contribute with a widely recognized quality of science and technology relevant to the NASA mission. Also, it is expected

that the Center reputation will attract an increasing number of minority students, both graduate and undergraduate, to study, acquire expertise, and become motivated to pursue careers in the fields relevant to NASA's mission. "

RESEARCH GOALS AND RESULTS

Nanocomposite materials for electro-optical applications. As technological demands impose more stringent requirements for reducing the physical size of optical electronic components, the scientific community is obligated to meet these needs for extraordinarily small devices. Several activities current in our laboratory are aimed at exploring some of the more fundamental aspects of what happens when matter is reduced to finite dimensions. For example, we are fabricating semiconductors and metals that are nanometers in size. These materials have a rich display of properties which differ significantly from those otherwise available. Some of these properties make them usable for fast all-optical switching devices, which could have great impact in telecommunications and all-optical computers.

In 1995, we have obtained and characterized, by Infrared and Raman Spectroscopies, Atomic Probe Spectroscopies and Differential Scanning Calorimetry, blue light emission for Germanium quantum dots in silica and fabricated silica substrates including quantum dots of Gallium Arsenide, Cadmium Selenide, Indium Phosphide and Gallium Phosphide, which show potential for advanced nonlinear optical applications.

Additional funding for this research has been provided by NASA's Marshall Space Flight Center and the Oak Ridge National Laboratory.

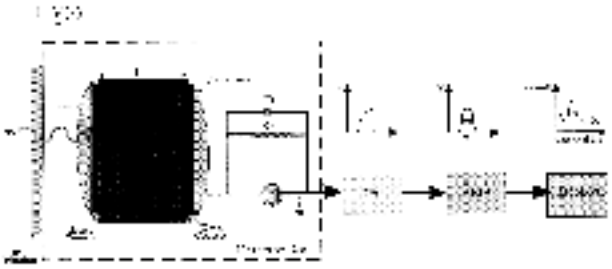

Figure 1. Block diagram of the X-ray and gamma ray room temperature semiconductor detector

Semiconductor Crystals. The Materials Science and the Surface Science groups at the Center focus on the study of the physical properties of semiconducting crystals (heavy metal iodides and II-VI compounds), the identification and understanding of the formation of defects, and the mechanisms by which they affect devices fabricated from these materials. The crystals are also produced commercially for use as X-ray and gamma-ray detectors for scientific, industrial, and medical applications. They offer the possibility of developing a portable imaging detector for X-rays and gamma-rays with the advantages of operating at room temperature instead of in the liquid nitrogen temperatures required by other detectors, and having greater radiation resistance than other conventional detectors.

Facilities at Fisk presently involved in the above activity are: a) Crystal Growth Labs, equipped with synthesis, purification and single growth systems, suitable for the processing of semiconductor materials, b) Surface Science Laboratory, with recently acquired ultrahigh vacuum spectroscopies (XPS/ AUGER) and probe microscopies (AFM/STM), and c) Crystal Characterization Labs, equipped with modern instrumentation acquired or developed at Fisk for thermal, optical, and electrical characterization of crystals and device evaluation.

Present activities include matched efforts and collaborations with other NASA groups (such as Marshall Space Flight Center) in the area of defect formation and microgravity effects during the crystal growth

processes and with Goddard Space Flight Center, where the focus of the research is in the actual implementation of these crystals and their use
on- board various spacecraft for extraterrestrial
missions.

Optical Fiber Materials. The Glass and Optical Materials group is conducting basic research on the linear and nonlinear optical properties of materials that have optical fiber applications. Past projects have dealt with both ion-implanted and bulk silicate and borate glasses containing highly polarizable ions, which, by virtue of their high nonlinear index of refraction and low optical absorption, have good figures of merit for optical switching and signal processing devices. Current research is focused primarily on the luminescence properties of rare earth dopants in heavy metal oxide glasses, and how these properties are related to the composition and structure of the host glass. Potential applications for these rare-earth doped glasses include fiber lasers and fiber Bragg gratings.

Fiber devices are especially attractive for aerospace applications since they combine the attributes of high performance, reliability, and compact size. Fiber lasers are simpler and more compact than many solid-state and glass laser systems, spectrally cleaner than diode lasers, and can be effectively pumped by semiconductor diodes. Diode pumped upconversion lasers can produce visible emissions and may offer an advantageous alternative for blue-green lasers, since blue and green diode lasers are not yet commercially available. The most commonly used rare-earth doped glasses for optical fiber devices have been silicate and fluoride based glasses. For some applications, however, silicate glasses are limited by their high vibrational energies, while the fluorides suffer from poor glass stability and chemical durability.

In 1995, we have developed and characterized, by Raman and photoluminescence spectroscopies and Differential Scanning Calorimetry, a series of rare-earth doped PbO-GeO2-TeO2 glasses, which have better mechanical strength, chemical durability, and thermal stability than fluoride glasses. Their vibrational energies are intermediate between those of silicates and fluorides. This means that they will have higher quantum efficiencies and provide more fluorescent emission than silicate-based glasses, making them better suited for devices such as fiber upconversion lasers.

PUBLICATIONS AND PRESENTATIONS

Research results obtained in the first 3-1/2 years have been reported in 64 publications in refereed scientific journals and 75 presentations in national and international conferences, issued as a book chapter, and registered as a U. S. patent.

HUMAN RESOURCES

The number of Ph.D. level personnel doing research in Photonics and supported by NASA, the University, and Center partners has increased from 7 in the original proposal to 13 in 1995.

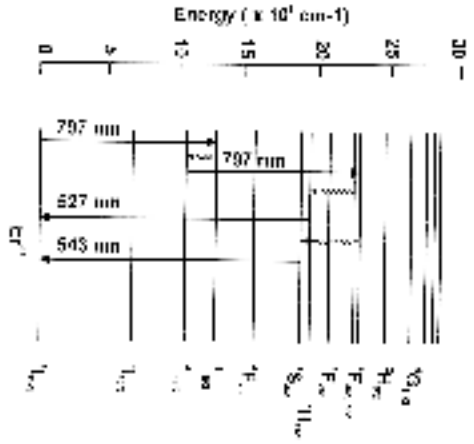

Figure 2. Energy level diagram of Er: PbO-GeO2-TeO2 glass showing the mechanism by which two near infrared photons are upconverted into a single green photon at either 527nm or 543nm. Zig-zag arrow indicate non-radiative transitions.

"Center For Nonlinear And
Nonequilibrium Aeroscience (CeNNAs)"
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Date of Original Award:1992
Report: The NASA/FAMU Center for Nonlinear and Nonequilibrium Aeroscience (CeNNAs) was founded to do research on the dynamics and the aerothermochemistry of gases and materials relevant to the NASA Aeronautics Enterprise. CeNNAs' investigations are currently focused on the dynamics of interfaces so as to extend propulsion regimes, enhance communications capabilities, and design materials that can survive adverse environments. The research is aimed at new insights on and new diagnostic procedures for turbulence and molecular relaxation processes in compressible neutral and ionized gases, aeroacoustics, propulsion dynamics, combustion, and heterogeneous nucleation. There are also programs of research on the characterization of stressed materials, film deposition processes, and on the fundamental physics of electron and atomic collisions in the reentry regime. Below is a sample of some of our major accomplishments this year.

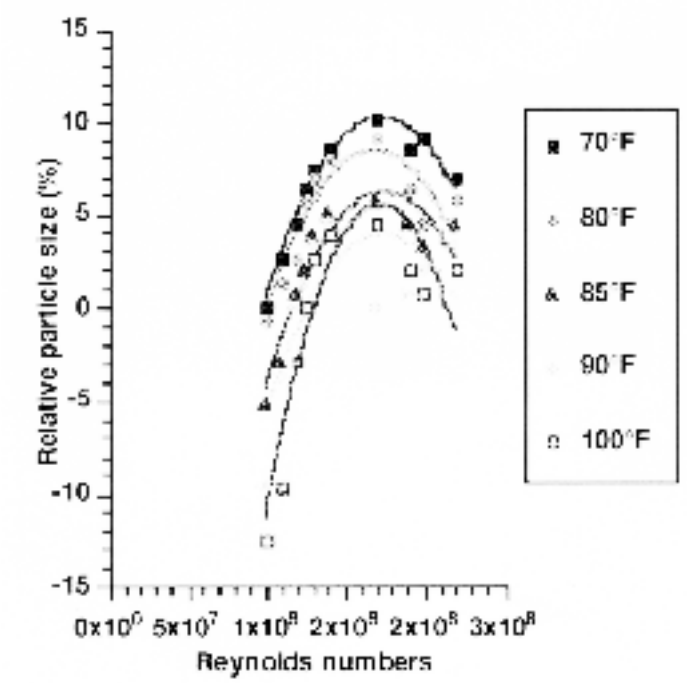

Figure 1. Turbulant Control of Condensate Droplet Sizes

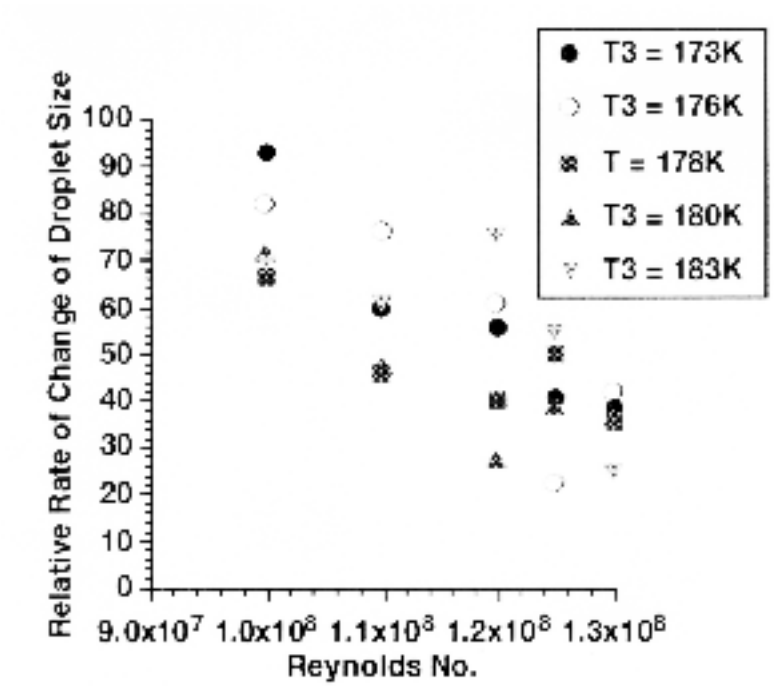

Figure 2. Evidence of Turbulant Distortion of Condensate Accretion Rate

TURBULENCE AND CONDENSATION

Heterogeneous nucleation and the subsequent droplet and crystal growth play a critical role in the contribution from PCS and vapor trails to atmospheric environmental concerns and in the development of ice crystals on environmentally exposed aerofoils. Yet the best growth rate theories are essentially ad

hoc and/or empirical, with very weak experimental confirmation of underlying physical principles. We have found a new clear dependence of droplet size on the strength of the turbulence. As Figure 1 shows, increasing the Reynolds number produces an increase in the relative sizes of the droplets in a manner which changes with both the temperature and the Reynolds number according to a standard strong coherence model. Furthermore, when the rate of droplet growth is measured by observing the change in droplet size at two locations, we find that the rate of change of droplet size is also dependent on the Reynolds number. (See Figure 2.) We show a temperature sensitivity in these results also. We expect to extend our investigations to low temperature regimes; we are particularly interested in the pressure and temperature conditions appropriate to sublimation. Under these conditions we expect to determine the role of both turbulence and temperature in the evolution of ice crystals, appropriate to high altitude jet trails and to the onset of icing on the wings of airplanes.

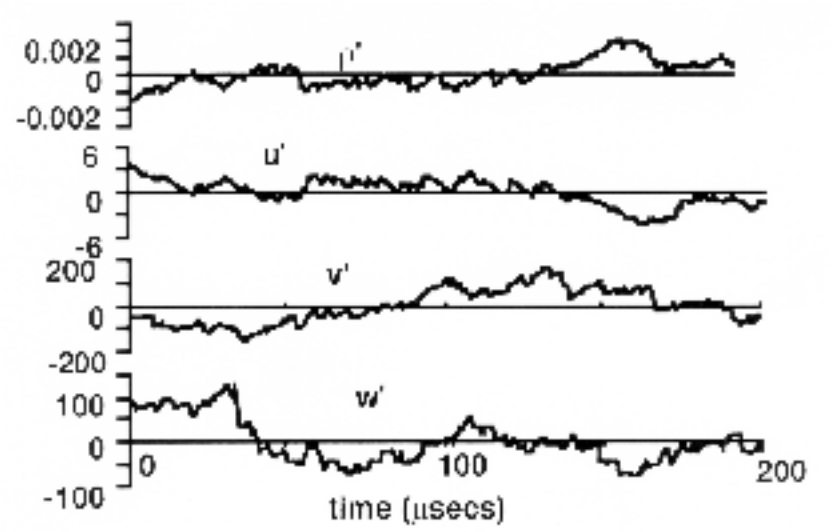

Figure 3. Direct Estimation Velocimetry Measurements at 5MHz

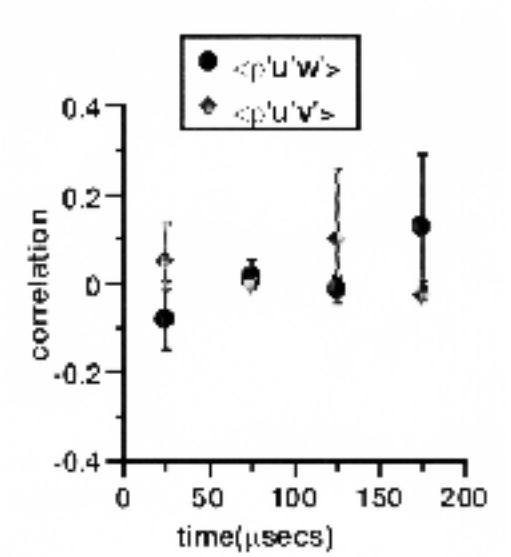

Figure 4. Evidence of Vanishing Triple Correlation

COMPRESSIBLE TURBULENT FLOW

Advances in turbulence physics are now intimately connected to the availability of comparisons between theoretical models and realistic generalizable experimental data. In particular, a rank ordering of modeling approximation techniques for strong turbulence requires a dedicated relationship between theoretical approaches and experimental facilities where the approaches can be tested. Using Direct Estimation Velocimetry in our Ludwieg Wind Tube Tunnel, we have performed simultaneous measurements of density and all components of velocity from laser-induced fluorescence at a data rate in excess of 2 MHz in a turbulent supersonic free shear layer. A sample of these data is given in Fig. 3. We thereby measure, with profound spatial and temporal resolution, the turbulent transport in a manner that will be useful for a wide variety of flow fields. Bursting effects are suppressed and the triple correlations remain near zero throughout the flow. Thus, our newest data show clear evidence of vanishing triple correlations. The averages of triple correlation terms <r'u'v'> and <r'u'w'> in consecutive time intervals are shown in Figure 4; specifically, the average value is 0.029 ± 0.04, which is statistically consistent with the prediction of a vanishing triple correlation. Thus, these measurements offer a first tentative confirmation of the validity of predictions on the closure issue in compressible turbulence in the theoretical approach first offered by Tsugé and Sagara. These results should therefore prove quite useful in the current efforts at enhancing the broad applicability of physics models for compressible turbulent flow.

Over the last two decades, the poor mixing properties of compressible shear layers have proven to be one of the major stumbling blocks in the development of efficient supersonic air breathing propulsion systems. This in turn imposes a limit on the design of modern supersonic aircraft. A unique new facility was designed to generate a two-dimensional countercurrent shear layer with a nominal convective Mach number of 2. A typical time-averaged Schlieren image of the countercurrent shear layer clearly reveals that the visual growth rate of the mixing layer with counterflow (i.e., the mixing layer between the two jets) is significantly higher than the corresponding mixing layer without counterflow (outside mixing layer). The enhancement in mixing rates of countercurrent shear layer was accompanied by the appearance of large turbulent structures in the shear layer and highly elevated fluctuating pressure levels, measured via fast-response pressure probes. These results further illustrate the intimate connection between turbulent transport properties and shear layer growth rates. In addition, the present study demonstrates the effectiveness of using counterflow to achieve mixing enhancement in highly compress-ible flows. The relative ease of implementing this technique, together with its robustness for various flow geometries and applicability over a large compressibility range, make it ideal for practical applications.

The superior performance of aircraft equipped with thrust vectoring nozzles in areas such as post-stall performance, reduced take-off distances, and overall greater control and maneuverability is well established. Laser sheet images showing vectoring in two directions have been obtained which clearly demonstrate that the jet can be completely directed into the suction chambers producing vectoring angles of up to 20 degrees. An engineering development model based on this study has been tested at NASA Langley Research Center in collaboration with Pratt and Whitney. The results obtained from this investigation are in excellent agreement with our laboratory scale model.

ACOUSTICS

The need to make modern fighter aircraft ‘stealthier’ with reduced infrared (IR) and acoustic (noise) signatures has been the impetus behind these investigations. Recent research has suggested that the addition of streamwise vorticity, or swirling flow, enhances the mixing of the hot jet exhaust gases with the colder ambient air, resulting in a reduced IR signature. In addition, the streamwise vorticity is also expected to significantly reduce the sideline noise from the supersonic jet engines, a property which may be exploited in both civil and military aircraft. A unique, diamond-shaped, converging-diverging (c-d), Mach 2 nozzle was designed for a detailed investigation of the effect of significant streamwise vorticity on the acoustic and IR characteristics of supersonic jets. The presence of distinct ‘rippled’ structures along the jet periphery is clearly visible in the laser light sheet images of the jet cross-sectional plane. These images, together with the results of pressure surveys conducted in the jet periphery, provide convincing

evidence of the presence of significant streamwise vorticity in the periphery of the diamond-shaped jet. The stream-wise vorticity increased the local thickness of the shear layer while only moderately influencing the jet diffusion rate. However, the effect of vorticity on the far-field noise was fairly significant; for a hot jet, a 5dB reduction in jet side-line noise was measured when compared to the noise properties of the more conventional round jets.

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Report: There have been many significant accomplishments in the Center's research programs over the past year. The fiber optic sensors group has developed new techniques for accurate fabrication of Bragg sensors, leading to collaborations with other NASA facilities and a patent disclosure. The photorefractive materials group has formed a collaboration with Deltronic Crystal Industries, a New Jersey based crystal growth company. This collaboration will focus on development and characterization of new nonlinear optical materials for high density holographic data storage. The non-intrusive spectroscopy group is developing electron beam and laser fluorescence techniques for flow field diagnostics. This work has potential applications in the Hyper-Flow Generator system at NASA Langley.

Several new physics faculty members, research scientists, post-doctoral fellows, and students joined the Center this year. Research Assistant Professor Dr. Thomas Chyba, Visiting Assistant Research Professor Dr. Thomas Zenker, Adjunct Professor Dr. Jack Fishman, and post-doctoral fellow Dr. Chuan He were recruited for the Center's lidar research effort. This group is participating in collaborative research with NASA Langley, as well as developing an off-campus lidar facility for remote sensing of the Hampton Roads metropolitan area. Research Assistant Professor Dr. Uwe Hommerich was recruited to head the laser materials development and spectroscopy group. Although he arrived here in July l995, he has already assembled and conducted several experiments in the laboratory, and has established collaborations with the NASA-URC Center for Photonic Materials and Devices at Fisk University, the Center for Materials Research at Norfolk State University, SPIRE Corporation, the University of Hamburg, and the University of Moscow.

The main objective of the fiber optic sensors group is to develop distributed sensors and fiber optic centered opto-electronic networks for the intelligent monitoring of phenomena in various aerospace and earth- bound structures. In particular, our aim is to fabricate a distributed sensor system using D-type and other special fibers that can be incorporated onto and underneath the surface of a structure in order to sense stress, strain, and pressure field variations.

The research efforts of the solid-state laser spectroscopy group are directed towards the development and characterization of new optical materials that are of interest for applications such as solid-state lasers, optical amplifiers, light-emitting diodes (LED's), phosphor materials, environmental sensors, and solar concentrators. Currently, the research focuses on material preparation, optical spectroscopy, theoretical modeling, and device demonstration of rare earth and/or transition metal ion doped solids. Material preparation will be carried out in cooperative research programs with universities and industrial partners. Most optical materials under current investigation are targeted toward the development of solid-state lasers for NASA's remote sensing program.

The research objectives of the laser development and lidar applications research group are: laser physics, the development of lasers for remote sensing of atmospheric processes, constituents and pollution, the

development of receivers and complete lidar systems, field measurements with these lidar systems, and interpretation of lidar and other remote sensing data to understand atmospheric chemistry and physics.

Photorefractive materials are becoming an attractive alternative media for ultra-high density data storage devices. The research objective of the photorefractive materials group is to understand the microscopic physical processes that determine the photorefractive properties of single crystal oxides, organic polymers, and semiconducting materials.

Advanced optical diagnostic techniques play a critical role in high-speed aerodynamics. The diagnostics used in the supersonic and hypersonic regimes are fundamentally different from those used at lower speeds. Historically, two methods have been used to understand fundamental physical phenomena, qualify flows, and validate computational models for complex and unsteady flows: conventional and non-intrusive optical methods. Conventional methods use in-situ probes of the hot-wire, pilot tube, or gas-sampling type for flow diagnosis. These methods are not suitable for diagnosis of supersonic and hypersonic flow fields because the chemistry of the flow changes when the probe is entered. An electron beam fluorescence (EBF) experiment has been developed to non-intrusively diagnose the solar thermal and electric propulsion (STEP) system at Hampton University and possibly the Hyper-flow Generator (HFG) system at the Measurement Science and Technology Branch at NASA LaRC. The hardware of the experimental setup, including a stainless steel test chamber, vacuum attachments to the test chamber, vacuum pumping systems, and a customized electron gun were designed, purchased, and installed, and preliminary measurements have been reported.

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Report:
CSTEA OBJECTIVES

- recruiting and training of graduate students in the fields of atmospheric sciences, engineering, physics, and chemistry;
- operation of space-based atmospheric flight experiments and theory;
- developing an interdisciplinary environment to support the above; and
- design and operation of a space-based atmos-pheric flight experiment with the collaboration of NASA and other laboratories.

STRATOSPHERIC WAKE
ANALYSIS PROJECT (SWAP)
The Stratospheric Wake Analysis Project (SWAP) is a research campaign conducted by researchers with CSTEA. The goal of SWAP is to determine the impact of stratospheric aircraft using in-situ, near- real-time measurements of gases and aerosols in the far wake region of the aircraft engine exhaust plumes. SWAP has recently completed several successful tests and data-taking flights using NASA's quartz crystal microbalance/surface acoustic wave cascade impactor (QCM/SAW) aboard NASA's ER-2 high-altitude research airplane. The QCM/SAW is an analytical instrument that is capable of measuring six size-fractionated distributions of aerosols and concentrations of trace gases down to parts per trillion (pptv) levels in the earth's stratosphere. Measurements have been made for ozone, sulfur dioxide, nitric acid, and hydrochloric acid. The stoichiometric composition of the aerosols can be determined through post-flight analysis of the quartz crystals.

The highlight of SWAP occurred on May 5, 1995, when CSTEA participated in a tandem flight involving two ER-2 airplanes. During this mission, a chase ER-2 was equipped with the QCM/SAW and was used to track the wake of a lead ER-2. This mission was the first and only time that two ER-2's have been deployed for these purposes. The plume from which the data were collected ranged in age from a few seconds to several minutes. These data represent the earliest sampling of stratospheric wakes to date. The chase plane encountered substantial localized turbulence while it tracked directly behind the lead plane by 10,000 feet. The ages of plumes intercepted by other means are typically an order of magnitude older. The success of this mission confirmed the feasibility of future studies of this sort for the characterization of the wakes of high-speed stratospheric aircraft. The lidar group at Clark-Atlanta University has a sub-contract from CSTEA to aid in developing a lidar system for the ER-2, which will detect and guide the pilot into the plume.

In cooperation with British Airways and Canada's Moncton Control Center, SWAP has also made two test flights of the QCM/SAW mounted on the ER-2 to sample the wake of the British Airways Concorde SST. The first of these flights tested the QCM/SAW and the communications between the ER-2 pilot and Moncton Control Center. The Concorde was not involved. For the second flight, air traffic controllers at Moncton directed the ER-2 toward the track of the Concorde. These flights will help SWAP develop techniques for the efficient interception of stratospheric wakes in future campaigns.

ATMOSPHERIC CHEMISTRY
The Atmospheric Chemistry group conducts experimental and theoretical research in the fields of photochemistry, IR and visible spectroscopy, synthesis, kinetics, free radical reactivity, calculational quantum chemistry, and the detection and measurement of atmospheric molecules.

REMOTE SENSING
The objectives of the Remote Sensing group have been to develop theory and techniques for the interpretation of remotely sensed data and to analyze remotely sensed data to investigate planetary atmospheres. The scientific details of these investigations have contributed to seven published and invited papers.

FLIGHT DYNAMICS SUPPORT OF SWAP AND SPACE PLATFORMS
The objective of this group is to analyze and calculate the trajectories of various ER-2 test flights from Moffett Field (Ames Research Center), CA and
ER-2/Concorde intercept test flights from Wallops Island to the Nova Scotia area, using both ER-2 GPS data and ground-based (topocentric) radar data from the Digby and Halifax, NS ground stations. The actual ER-2 intercept strategy will be developed based on this information and will be updated by using a lidar sensing unit which is planned to be attached to a ground-based platform and later installed on the ER-2. This part of the research is jointly conducted with the University of Colorado (Boulder) under the direction of Dr. George Morgenthaler.

Another task involves the structural analyses and qualification of a proposed mass spectrometer that could be added to the ER-2 QCM flight instrumentation on the lower ER-2 pod. Preliminary analyses of the ER-2 and Concorde trajectory data indicates that the ER-2 can be closely directed to follow the actual Concorde flight path. The subsequent challenge is to determine an intercept strategy for the ER-2 to successfully pursue the wake of the Concorde at a safe distance downstream so that turbulence can be avoided. Preliminary analysis has commenced on the structural analysis of the QCM instrumentation unit as attached to the ER-2 pod, initially without the addition of the mass spectrometer.

Finally, within the last nine months three journal articles have been published related to previous CSTEA work on space platforms and one conference paper presentation.

SENSORS AND DETECTORS
The piezoelectricity property of crystals has been used to develop the class of sensors, noted above, known as quartz crystal microbalances (QCMs) or detectors. The frequency of vibration is directly related

to the mass of the crystals. Thin polymer coatings of various solutions can be deposited on the surface of these materials, which make them sensitive to various chemical compounds such as water vapor, ammonia or common air contaminant, hydrocarbons, carbon monoxide, hydrogen, chloride, mercury, nitrogen dioxide, explosive vapors, organophosphorous compounds, ozone, sulfur dioxide, etc. Many of these compounds and their levels in the atmosphere are very important to NASA, the deterioration of the ozone, and future supersonic aircraft.

The development of QCM has allowed detection sensitivity of less than 1 ng/cm2 of the various compounds named above. In this part of the research at CSTEA, we are developing microbalances with silicon carbide and other wide bandgap semiconductor materials. These materials, because of the physical properties (larger acoustic velocity), should increase the sensitivity of these detectors to at least 0.1ng/cm2, which will allow application to many atmospheric tests, and should be applicable to the effects of supersonic and hypersonic aircraft on the ozone layer and the earth atmosphere in general.

"Development of a Minority University Space Medicine and Life Sciences Research Center"
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Abstract: The objectives of the proposed MUSLRC are to: 1) develop the core infrastructure for space medicine and life sciences research; 2) develop the research capabilities and experiences in the area of space medicine and life sciences by existing faculty; 3) support the MUSLRC expansion through the recruitment of two additional faculty; 4) develop a student research training component in space medicine and life sciences; 5) develop advanced graduate courses for the predoctoral biomedical sciences program that will provide for a concentration in space medicine; 6) provide postdoctoral training in space medicine and life sciences; and 7) develop collaborative relationships with NASA, other universities, and private industry.

The long-term goals for the proposed MUSLRC are to develop the Center to produce exceptionally trained minority and women scientists in space medicine and gravitational biology research, and to provide a critical mass of faculty and other personnel through the core program of the center to strengthen the MUSLRC.

The proposed MUSLRC will consist of three parts: 1) The MUSLRC Office, which will direct all MUSLRC programs and develop the student research training and graduate program components; 2) The Core Program, which will develop the core infrastructure for gravitational biology research and provide additional faculty and postdoctoral research associates; and 3) The MUSLRC Research Program, which will provide support for the development of ground-based research to assess the mechanisms underlying the cardiovascular, musculoskeletal, and neuronal effects of microgravity. These research groups will interact through collaborative research and planned activities with other MSM units.

The proposed multidisciplinary studies will be carried out using the following microgravity models: the low-shear horizontally rotating bioreactor for cellular studies; the head-down tilt hindlimb suspended rat model; and the acute/chronic bed-rest head-down tilt human model. All three research groups will use these models and thus obtain data that can be integrated to provide a more precise understanding of the physiological responses to microgravity. These different components are complementary and will result in the MUSLRC developing into a multifaceted research center. The support for MUSLRC infrastructure will provide the equipment, space (through renovations), and technical personnel necessary for the success of the research and training components. The additional faculty are proposed as a mechanism for increasing the research activities of the MUSLRC and the available faculty for student research training.

This is a necessary component in the development of the MUSLRC, one which offers the opportunity to increase the medical school faculty having expertise in this area of research and education.

The training component of the proposed MUSLRC will increase the number of minority students exposed to the area of space medicine and life sciences research. The benefit to NASA is the immediate increase in minority postdoctoral level researchers involved in this important area.

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Report: The major research objectives of the Center for Aerospace Research, a NASA Center of Research Excellence (NASA-CORE), are to establish a strong research capability in aerospace engineering and to advance the state-of-the-art in aerospace research and development through innovative basic research within the framework of a strong interdisciplinary philosophy.

The research activities of the Center are carried out in five interdisciplinary research components: Aerospace Structures, Controls and Guidance, Computational Fluid Dynamics (CFD), Human-Machine Systems, and Propulsion. The five components conduct innovative research for the development of new high-speed aircraft and spacecraft technologies.

AEROSPACE STRUCTURES
In aerospace structures research, geometrically exact modeling techniques for highly flexible isotropic and composite structures undergoing large displacements and rotations have been developed. A new displacement-based finite-element code, GESA (Geometrically Exact Structural Analysis), is under development. GESA implements the geometrically exact structural theories to better predict structural behavior of aircraft and spacecraft under large dynamic loads. This new technology will significantly improve the analysis and design of lightweight aerospace structures, with potential applications in high-speed commercial transport (HSCT) and large deployable spacecraft.

CONTROL AND GUIDANCE
A new technology based on fuzzy logic (hybrid fuzzy PID, HFPID) that mimics human response to changing HSCT flying characteristics has been developed by the Controls and Guidance group. The role of hierarchy in the design of fuzzy logic controllers (FLCs) has been investigated. This technology has applications in the control and suppression of vibration in high-speed aircraft, vibrating plates, VSTOL aircraft, etc.

COMPUTATIONAL FLUID DYNAMICS
In Computational Fluid Dynamics (CFD), new computational and prediction tools have been developed to better predict the behavior of the flow over high-speed aircraft and in propulsion systems. A new "eddy viscosity transport" model for turbulent flow prediction has been developed to give more accurate surface pressure, skin friction, and heat transfer characteristics. This will aid the design of better "aerodynamic" geometries for aircraft and propulsion systems. Compressible dissipation models have been developed for use with two-equation turbulence modeling to investigate the effect of pressure dilatation on the growth of supersonic mixing layers. A waverider research program has been designed to develop a multidisciplinary design methodology, which will provide hypersonic vehicle configurations for a wide range of missions.

HUMAN-MACHINE SYSTEMS
Research in Human-Machine Systems seeks to address pilot characteristics that impact handling qualities of supersonic and hypersonic aircraft. Human operator models based on control theories are being developed to define multiattribute experiences of the human pilot and pilot-vehicle integration. Models in human response errors, time, and orientation have been developed, with potential applications in high speed aircraft. An augmented control model of the human operator is being developed to address the effects of interdisciplinary phenomena such as (panel) flutter and vibration induced motion on high-speed vehicle handling qualities.

PROPULSION
Research in propulsion began in earnest this year. Research interests in propulsion include high-speed propulsion system analysis and design, propulsion system/airframe integration, and multidisciplinary optimization (MDO). The technologies developed from this research have potential applications in HSCT and hypersonic vehicle design.

NASA-CORE
NASA-CORE is conducting leading edge research. Work in fuzzy logic controllers has been commended by Mr. Daniel Goldin, NASA Administrator, and a patent for the HFPID controller is pending. Research in deformable and highly flexible structures and CFD prediction methodologies are invaluable to NASA in high-speed aircraft design. Human-machine interfaces for high-speed aircraft and supersonic/hypersonic propulsion are critical technologies.

"Center for Applied Radiation Research (CARR)"
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Abstract: The space radiation environment can have serious effects on the operation of space shuttles, space stations, geosynchronous satellites, and deep space probes due to high-energy charged particles. Multiple single-event upsets occurring in spacecraft (Voyager 2, Magellan), tracking and data relay satellites (TDRS), and communication satellites (GEOS), causing errors ranging from recoverable data errors to the generation of phantom commands that could have fired thrusters, have been reported. CARR's main goal is to significantly contribute to NASA's vast technology base, in particular to provide enabling technologies - new materials, electronics, shielding, and radioprotectorants for humans - that will make major NASA missions even more successful, safer, and less costly. We will examine the space radiation environment and develop an effective ground based testbed in the areas of Radiation Effects on Electronic and Photonic Systems, and on Bio-Systems. The outcomes of CARR research are expected to have tremendous dual-use potential in addition to initiating, at PVAMU and other HBCUs/OMUs, related and new research areas. With the existing and proposed new equipment, and the increased expertise of the research faculty, CARR will become a true Center of Excellence, conducting and attracting funds from mainstream research.

At the same time we plan to develop the Human Resource Potential of minority students through the expansion of innovative programs (such as our Joint Explorer Post with Hempstead High School at the pre-college level, and enhanced recruiting and tracking at the undergraduate and graduate levels), thus enlarging the number of minorities in the pipeline for terminal degrees in science, mathematics, engineering, and technology (SMET) disciplines.

DESCRIPTION OF PROPOSED PROGRAM

The proposed program is based on four components: research, education/training, outreach, and technology transfer. CARR will conduct research in three technical areas - Space Environment and Simulation, Radiation Effects on Electronic and Photonic Systems, and Radiation Effects on Bio-Systems - covering a range of topics for research, while keeping to the single unifying theme of radiation effects. The research that we propose focuses on failure and upset mechanisms in devices and circuits, the physiology and immunology of the female reproductive system, and their degradation and tolerance to radiation. In addition, CARR will establish an ongoing program wherein highly motivated students will be given opportunities to work with CARR researchers, who will mentor these students toward advanced academic careers in SMET areas or entry into the nation's industry workforce.

Our initial work emphasizes CMOS systems because of their widespread use. However, we expect new developments in our materials effort to expand our work into high dielectric constant insulators for DRAM storage capacitors, high Tc superconductors for possible Josephson junction applications, and novel semiconductors. And finally, our study of cells will be related to guidelines for human habitation and flight crew.

SIGNIFICANCE OF THE
PROPOSED WORK TO NASA

The precise management, operation, and activities of the NASA missions - manned flights, unmanned exploratory probes, and HSCT - utilize highly complex electronic systems exposed to radiation of intensity, composition, and duration not encountered on earth and in ways not previously experienced, and failure rates are expected to be less than 1 failure in 109 hours. Clearly, this is unrealistic. Our proposed research will yield explicit design guidelines and predictions for electronic circuits, novel materials, and efficiency of radioprotectorants for humans, and will significantly increase radiation immunity, thus enhancing the mission safety while saving NASA millions of dollars.

SIGNIFICANCE OF THE PROPOSED
WORK TO INDUSTRY

Our research will provide technology transfer to commercial communication satellites. In-process radiation induced defects are a yield limiting factor in IC technology. Semiconductor industry interests provide a return to NASA in the availability of more current technology for NASA missions, thus emphasizing the dual-use nature of CARR research.

PARTNERSHIPS AND COLLABORATIONS

We plan to utilize our existing partnerships and collaborations with other universities, Government laboratories, and industry to strengthen the Center in several ways. A few examples are: inviting experts to interact with CARR researchers, performing tasks that support or are complementary to CARR's tasks, providing summer internships to faculty and students at other HBCUs/OMUs, work with NASA and other organizations in affecting technology transfer, and providing specialized courses and workshops.

"Center for Automated Space Science"

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Abstract: We propose to establish a Center for Automated Space Sciences (CASS). The successful implementation of this center will expand the Nation's aerospace research base and will advance the scientific and technological concepts for autonomous space systems. Additionally, the Center will produce

a dynamic research atmosphere that will motivate faculty and provide a challenging environment for students, specifically underrepresented minorities. The goal is to prepare faculty for mainstream competition and students for advanced studies in NASA-related fields.

The technical plan is to build on TSU's existing strengths in control systems research and automated astronomy to solve problems of interest to NASA and to bring TSU to the point of participation in space missions. The proposed CASS Center will utilize space-based observations and a completely automated ground-based observatory - consisting of four currently operating robotic photometric telescopes, a nearly complete automatic imaging telescope, and a proposed automatic spectroscopic telescope (AST) - to perform research relevant to three of the five NASA Strategic Enterprises: Space Technology, Scientific Research, and Mission to Planet Earth.

In order to accomplish this task, Tennessee State University is fully committed to the support of the Center. Specifically, TSU has committed $650,000 in cost-sharing to offset a portion of the AST construction costs, made provision for 3,900 sq. ft. of research space, will provide access and use of the university's academic and administrative computer facilities, and has given tentative approval for a cooperative 2+2 and 2+3 degree program.

The CASS Center will be greatly strengthened by two research partners, Western Kentucky University (WKU) and South Carolina State university (SCSU). The Head of the Department of Physics and Astronomy at WKU is an African-American astrophysicist who is dedicated to increasing the number of underrepresented minorities in the space sciences. Also, there are four other professional astronomers on the faculty who will not only contribute to the research effort but also to student recruitment and retention. SCSU is an HBCU, and will provide a large pool of minority students for inclusion in the research program.

The existing collaboration of four NASA field centers (MSFC, LaRC, ARC, and GSFC) will enhance and strengthen the technical plan and will facilitate the dissemination of research results. Through a partnership arrangement, the Harvard-Smithsonian Center for Astrophysics will provide the observatory site and associated services at the F.L. Whipple Observatory at Mt. Hopkins, AZ. Collaborators from various universities (Vanderbilt, Rice, Texas A&M, and UT-Arlington) will provide a strong scientific resource for the CASS Center.

"Tuskegee University NASA Center for Food Production, Processing, and Waste Management in Controlled Ecological Support Systems (TUNACC)"

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Report: The overall goal of the Tuskegee University Center for Food Production, Processing, and Waste Management for CELSS is to provide tested information and technologies for bioregenerative food production systems for life support on space missions. The Center is developing information, computer simulated models, methodologies, and technology for sweetpotato and peanut biomass production and processing, inclusive of waste management and recycling. Teams of life scientists and engineers work together on long-term goals and specific objectives, with the following accomplishments during the past year.

Growing systems and
environmental factors (GRO)
Studies using 11 growth chambers solely dedicated to the project included: effects of CO2, temperature, plant defoliation, nutrient solution makeup and protocol, and the effect of light quality. The greenhouse is used for preliminary studies.

Storage root yield for TU-155' and 'GaJet' sweetpotato were significantly higher at a CO2 enrichment of 750 ppm compared to ambient (400 ppm) but declined at 1000 ppm. This finding was consistent in all the experimental trials. Generally, all other growth responses followed a similar trend. In other CO2 studies on three peanut varieties, all responded favorably to increased CO2 compared to ambient conditions.

Studies on sweetpotato growth using varying day/night (diurnal) temperatures of 30/24, 28/22, 26/20 and 24/18C have indicated high storage root production at all but the highest temperature regime, where values dropped, suggesting that the optimum temperature may be between 24/18 to 28/22C. Preliminary tests show no storage root formation at 18/12 C. These results indicate the best temperatures for sweetpotato growth, and can help determine which crops can best be grown in a CELSS with sweetpotato.

Sweetpotatoes grown using only cool white fluorescent lamps had cooler leaf temperatures (up to 2C) and produced yields similar to or greater than those grown with both fluorescent and incandescent lamps.

When compared to the control (14% ammonium), nutrient solution studies in which the nitrogen source varied in its ammonium/nitrate ratio showed that sweetpotato plants may tolerate between 20 to 50% of their N from ammonium sources without adverse effects on yield. Nutrient solution replenishment with a 10 times modified half or quarter Hoagland solution concentrate did not significantly influence yield. Preliminary results of defoliating and deflowering peanuts at different times during growth indicated that pod number and fresh weight, shoot fresh weight, final leaf number, and leaf area were not significantly affected by these procedures, but in all cases yields tended to be lower than for untouched plants.

Germplasm Development Group (GED)
Studies to evaluate sweetpotato germplasm for high dry matter content (above 25%) were conducted in field trials to select appropriate germplasm for the Tuskegee University hydroponic nutrient film technique (NFT). Of the 20 breeding lines that have been evaluated in the NFT system to date, white flesh genotypes generally produced higher yields in the field than orange-flesh genotypes, but not in NFT.

Primary biotechnology accomplishments this year were the successful development and testing of transgenic sweetpotato plants and the first-ever identification of polymorphic DNA markers in peanut. An improved technique resulting in rapid, continuous production of somatic embryos was developed. Many transgenic sweetpotato plants expressing foreign genes have been developed using the Agrobacterium vector system. PCR and Southern gel blot analysis have been done on transgenic sweetpotato plants, with the presence and integration of foreign genes in the sweetpotato genome confirmed. Transgenic sweetpotato plants also have been evaluated for growth, phenotypic and agronomic traits using NFT.

Peanut (Arachis hypogaea) was unique in its response to molecular analysis because many RFLP and RAPD studies failed to detect any DNA polymorphism within cultivated species. The DNA Amplification Fingerprinting (DAF) approach using Stoffel fragment Taq polymerase, vinyl-polymer of polyacrylamide gel and silver staining have resulted in the production of complex but clear fingerprints. Recently, the new "Amplified fragment length polymorphism" (AFLP) approach has identified additional DNA markers.

Waste Management and Recycling Group (WAM)
In a series of experiments, sweetpotato plant material (biomass) collected in a bioreactor was filtered and subjected to amylolytic degradation using isolates naturally found in the field. The filtrate is now being evaluated as a crop nutrient medium. Genetic characterization of lignocellulolytic isolates was concluded and that of other biodegradative isolates begun.

The culture collection of microbial biodegradative agents was augmented with the isolation of natural organisms with the potential for denitrification, starch degraders, cellulose degraders, and sulfate reducers—all with the ability to hydrolyze sweetpotato waste. These organisms are currently being used in experiments to assess their potential in the cycling of sweetpotato waste into inorganic nutrients for crop growth. Oyster mushrooms have also been produced on inedible sweetpotato/peanut biomass.

When a greenhouse nutrient solution study was undertaken to evaluate the effects of applying additional potassium, either incorporated in the 10X MHH stock or in addition to it, the foliar biomass was reduced at harvest. There was also a reduction in waste biomass produced with these treatments.

Microgravity Applications and Controls Group (MAC)
Several porous plate and tube membrane systems had successful sweetpotato growth, but foliage and storage root yields were less than in NFT due to reduced nutrient solution availability. To increase availability to roots, pressure plates were used in one system, along with a full, not a modified half, Hoagland solution, doubling yields in a greenhouse trial. This system and a nutrient delivery system with an expandable root boundary are being tested in growth chambers. The latter system has an expandable bag around the plant root zone, isolating it from the foliage by a padded sealant through which the plant stem passes. The expandable boundary chamber allows for expansion of the root zone volume, through longitudinal pleats, as the plant grows. Two units have been evaluated in a greenhouse trial using Tuskegee breeding clone TU-82-155 for 120 days.

Nutrition and Food Processing Group (NAF)
Research accomplishments have included sweetpotato treatment analyses, space menu development, and sweetpotato product development. Nutritive analyses and comparisons are being completed on sweetpotato storage roots grown under elevated CO2 and ambient conditions. Space menus have been developed using CELSS crops by examining crew caloric and RDA needs.
Plant Modeling Group (PAM)
The primary effort of PAM has been to establish a database for a sweetpotato plant growth curve based on plant behavior in a closed environment. This has required collection of data from existing experiments, assessment and analysis of these data followed by filling in gaps in the database with experiments designed to achieve that end. One such experiment involved a sequential harvest during which data was collected on a biweekly basis to provide baseline data for the plant growth model. ‘TU-155’ was the variety used and the experiment focused on the timing within the growth cycle when different physiological events would occur, especially those related to storage root enlargement.

“The Center for Autonomous Control Engineering (ACE)”
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Abstract: The vision of ACE is to:
- increase significantly the number of minority M.S. and Ph.D. degrees awarded in engineering fields related to NASA’s needs;
- become a vital resource for cost-effective research in control technology related to NASA’s mission;
- and become a self-supporting research group with a reputation for delivering quality results on-time and within budget.

We have chosen automatic control engineering as the Center focus because control systems form an integral part of many NASA systems. We believe that we can play a substantial role in developing technology that NASA can use immediately. ACE believes that the best way to train students is to create a realistic environment where real problems are presented. In this way, ACE will implement a program of results-oriented research for NASA Centers' projects as well as provide training for minority students. We have chosen JPL as our partner in this endeavor because many of the projects at JPL relate to ACE strengths. However, we anticipate expanding our approach to all NASA Centers as well as industry. The technical program of ACE supports four of the five NASA Strategic Enterprises as stated in the NASA Strategic Plan of May 1994. ACE has aligned its strengths to coincide with those of JPL, our partner in this proposal. The major intersection between ACE and NASA's mission resides in the Space Science and Space Technology Enterprises. Secondary interaction is found in Mission to Planet Earth and Human Exploration and Development of Space.

We have formed a strategic team of academic institutions to collaborate in this Center, each with a unique student population and perspective. The University of New Mexico (UNM), a Carnegie Research I University and a Minority Institution (MI), with a dual commitment to excellence in research and opportunities for minorities, leads the team. Next, we have North Carolina A&T (NC A&T), an HBCU, which has a relatively new Ph.D. program. Finally, we have New Mexico Highlands University (NMHU), a Minority Institution with no Ph.D. Program. This team will focus on understanding the fundamental reasons why minorities choose not to pursue the Ph.D. and develop innovative solutions to fix the problem. NCA&T forms the basis for African-American recruitment. UNM and NMHU serve the Hispanic and Native American populations. We also have a commitment from the American Indian Science Technology Education Consortium (AISTEC) to help ACE find qualified Native Americans from their consortium of tribal colleges. This liaison between ACE and AISTEC is mutually beneficial since it will help Native American students find their way through the education pipeline.

We believe that our impact on NASA research centers will be the development of new science and technology concepts that are immediately useful. However, this is not enough. ACE must also develop the infrastructure that will prepare minority faculty and graduate students to participate in mainstream research. We have a simple yet efficient strategy to achieve this goal. Since NASA Centers will not need to pay the university team for its research effort (URC provides these funds for five years), ACE will become increasingly important to NASA projects. As URC funding declines over time, we believe that NASA project funds will more than compensate, since NASA project managers will recognize ACE as valuable. For the same reason, we anticipate industry support.
We believe that ACE provides the mechanism to team with NASA Centers in a very productive manner, but for success we need several ingredients:

- clearly defined goals and strategies;
- a team of dedicated faculty with innovative ideas for research projects directly applicable to NASA Center needs;
- innovative yet practical strategies to aggressively recruit and retain minority graduate students and faculty;
- strong management structure to coordinate institutions and ensure the delivery of research results; and
- NASA support to build the Center infrastructure, reach critical mass in chosen technical thrust areas, and support students during the start-up of the Center.

We have some innovative ideas, a plan to realize those ideas, a talented team of scientists and engineers, and a management structure to ensure success. The administrations of all three universities have been extremely supportive regarding ACE.

"Tropical Center for Earth and Space Studies"
Principal Investigator: Dr. Rafael Fernandez-Sein

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Date of Original Award: 1995

Abstract: We propose to establish a Tropical Center for Space and Earth Studies (TCESS). The Center will enhance the Laboratory for Applied Remote Sensing and Image Processing (LARSIP), funded for five years by NSF in 1988 and renewed for a second five years in 1993. Funding for students will be provided by the University of Puerto Rico (UPR) in the form of direct cost-sharing. In addition, UPR will also provide funding for new equipment. We anticipate that Fomento (Puerto Rico Economic Development Administration) will finance additional equipment and major infrastructure investments. Some research projects will be directly supported by Raytheon Company, which will act as an industrial partner. TCESS is divided administratively into five components: 1) the Space Information Laboratory (SIL); 2) Earth System Studies (ESS); 3) Advanced Automated Image Analysis (AAIA) for Remotely Sensed Data; 4) Sensor Materials and Electronics for Space Applications (SMESA); and 5) Outreach and Education.

The Space Information Laboratory will build on the foundations of LARSIP and the contributions from NASA, UPR, and Fomento. UPRM will install and operate a Synthetic Aperture Radar (SAR) and HRPT tracking stations. These will be national facilities, open by invitation to scientists and engineers in a bilingual environment. We believe that this Laboratory has great opportunities for research applied to the problems of the tropical circum-Caribbean, with excellent prospects for long-term support from UPR and other federal funding agencies, as well as local and regional government

The Earth Systems Studies component contains two working groups, both of which have participated in other NASA programs. The Geology group will investigate surface deformation of Lesser Antillean island arc volcanoes. The Marine Sciences group will investigate the effects of the thinning of the ozone layer and its effects of surface UV radiation modulation on the development of plant screening pigments.

The Advanced Analysis Information Systems group from Electrical and Computer Engineering will investigate new image processing algorithms and techniques for storage, processing, and dissemination of remotely sensed data using high-speed streams, with implications for SAR processing. This project will be partially funded by Raytheon. The Sensor Materials and Electronics for Space Applications will investigate a number of materials with special properties suitable for space sensors. Techniques and materials for power conversion electronics for spacecraft will also be studied.

An Outreach and Education component will work in concert with TCESS to further enhance SMET student participation. As an extension to the successful “Science on Wheels” project, we propose a “Space Communications on Wheels” van that will bring space and earth studies within reach of the high school students in Puerto Rico. UPRM will also seek to develop courses containing space technology in all the represented disciplines of earth and space phenomena. A Technology Transfer Internship Program will allow professors and students to visit national laboratories, universities, Raytheon, and NASA field centers to facilitate technology transfer and encourage advanced studies.

“Pan-American Center for Earth and Environmental Studies”
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Date of Original Award: 1995

Abstract: UTEP requests five-year funding to establish the Pan American Center for Earth and Environmental Studies (PACES), which will conduct basic and applied research contributing to NASA's Mission to Planet Earth. PACES will enable researchers to develop an improved understanding of geological, ecological, and environmental processes and changes in land usage taking place in the southwestern United States and northern Mexico. Complementing this research mission will be an educational mission to produce highly qualified minority scientists and engineers.

The core faculty of the PACES center, who have worked together previously on federal and state funded projects and served as research mentors to large numbers of minority scientists and engineers, will conduct research in three areas: 1) geological studies of the Rio Grande Rift Region, 2) studies of human environmental impacts, and 3) investigations of high-level languages for processing large databases. Faculty associated with PACES will also seek additional opportunities to expand the research activities by leveraging Center resources. High-level guidance for PACE's activities will be provided by an external advisory board of distinguished scientists and engineers drawn from academia, government, and industry.

The PACES center will collaborate with two NASA field Centers (Goddard Space Flight Center and Ames Research Center), the Jet Propulsion Laboratory (JPL), the Consortium for International Earth Science Information Network (CIESIN), two major universities (California State University, Los Angeles and the University of Texas at San Antonio), and Research Analysis and Maintenance, Inc. These organizations have been selected as collaborators because of their participation in NASA's Mission to Planet Earth and their expertise in the technologies underpinning PACES.

In addition to conducting basic research, PACES will offer summer fellowships to students and faculty, establish a series of technical seminars, network with external organizations that might benefit from access to the data and technologies of the Center, publish a newsletter, and implement means of technology transfer and information dissemination and exchange. During each year of the grant, PACES will provide research opportunities to a minimum of 24 students.

The Center will provide vital support to NASA's Mission to Planet Earth by providing data and information on the southwestern U.S. and northern Mexico, a region that is experiencing significant aspects of global change. Changes in this region are analogous to those taking place in other arid and semi-arid locales around the world. PACES will also contribute much-needed research in defining high-level tools for processing and analyzing remotely sensed data. Current technology allows us to acquire and store huge amounts of data, yet it is still difficult to access and analyze these data to produce information that can be used by scientists and policy makers. PACES will assist NASA in addressing this need.

Institutional Research Awards for Minority Institutions (IRA)

NASA's Office of Equal Opportunity Programs designed the Institutional Research Awards (IRA) program to provide a quality learning and research environment for underrepresented minorities and to enhance cultural diversity in the Agency's sponsored research community. The Agency's objectives are to expand opportunities and to strengthen relationships with minority education institutions that have a demonstrated record in graduating students in science, engineering, and technology and which have not received significant amounts of NASA funding.

Through IRA funding, minority institutions and researchers are given the opportunity to enhance their research and communications capabilities in NASA-related fields, which provides the additional benefit of increasing their ability to enter the mainstream competitive research process. Upon successful completion of the IRA program, institutions should be qualified to compete in the University Research Centers (URC) for minority institutions program. In the first year of the IRA program, 1994, six research projects were funded. In the second year of the program, 1995, seven additional programs were funded to focus on the establishment of regional communications networks.

Sixty students were involved in URC research projects during the current funding year: 8 at the Ph.D. level; 19 at the M.S. level; and 33 at the B.S. level. 57% were male and 43% were female. Eighty two percent were members of underrepresented ethnic minority groups: 63% at the Ph.D. level; 74% at the M.S. level; and 91% at the B.S. level.

Abstracts and reports of all of the programs funded to date follow.

RESEARCH PROJECTS

"The Use of Decentralized Control in Design of a Large Segmented Space Reflector"
Principal Investigator: Dr. Helen Boussalis
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Report: California State University, Los Angeles (CSULA), one of 20 campuses in The California State University (CSU), is located on the eastern edge of the city of Los Angeles at the center of one of the largest concentrations of ethnic minority groups in the nation. Three-quarters of CSULA's students are from ethnic minority groups. CSULA, an officially designated Minority Institution (MI), is the only public four-year institution in California eligible for membership in The Hispanic Association of Colleges. CSULA is also the only MI in California with an accredited Engineering School. CSULA awards the highest proportion of science and engineering baccalaureates to African-American and Hispanic students of all California Public Schools.

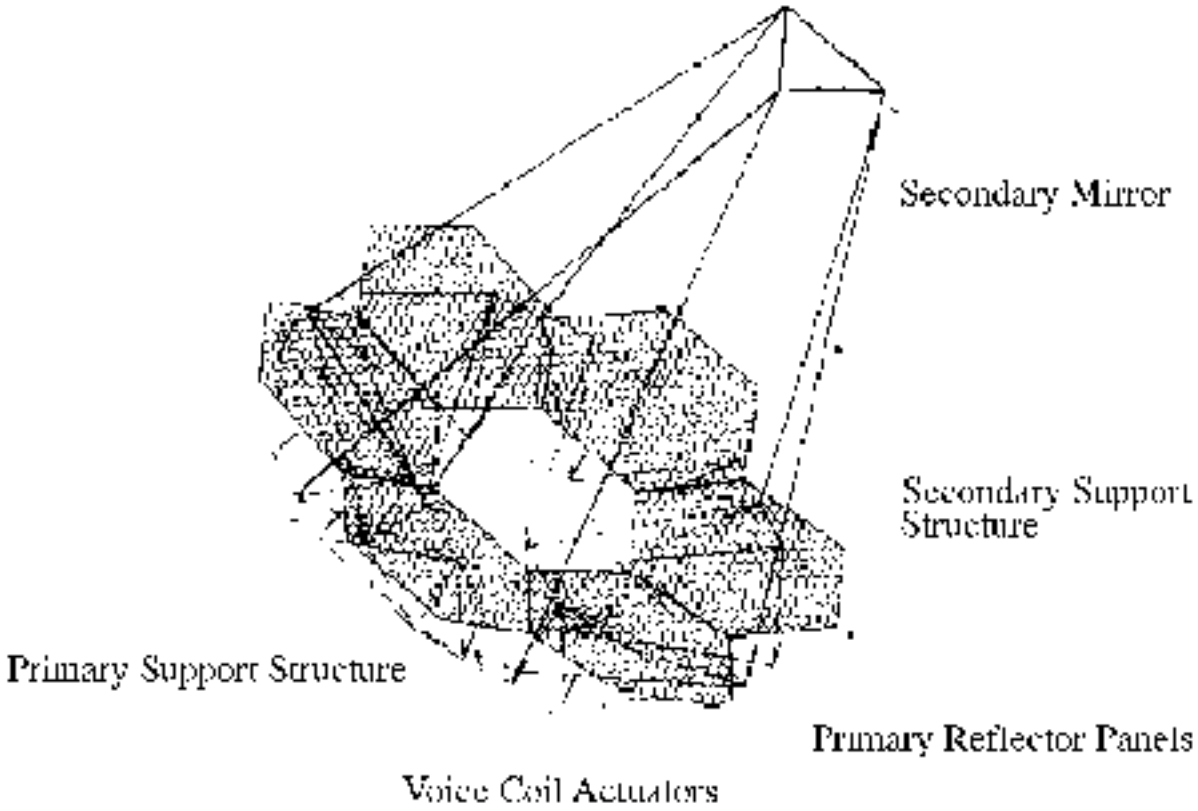


Figure1. Telescope Concept

The objective of CSULA's Control and Structures Research Laboratory is to house a segmented reflector telescope testbed (Figure 1), which will be designed and fabricated at Cal State L.A. The testbed is intended to serve as a generic experimental facility capable of performing experiments that simulate the complex dynamic behavior of a large segmented optical system. A monolithic reflector depends on the mechanical properties of its material to provide the dimensional stability required for good optical performance. A reflector built from segments relies on its support structure for stiffness and rigidity and an active control system to maintain alignment of segmented reflectors.

The laboratory can be used as an experimental facility for addressing problems associated with structural dynamics, control of multi-input/multi-output systems, optics, electronics, and actuator and sensor design.

Description of the research goals and some of the accomplishments of the two active component areas of the CSRL are given below.

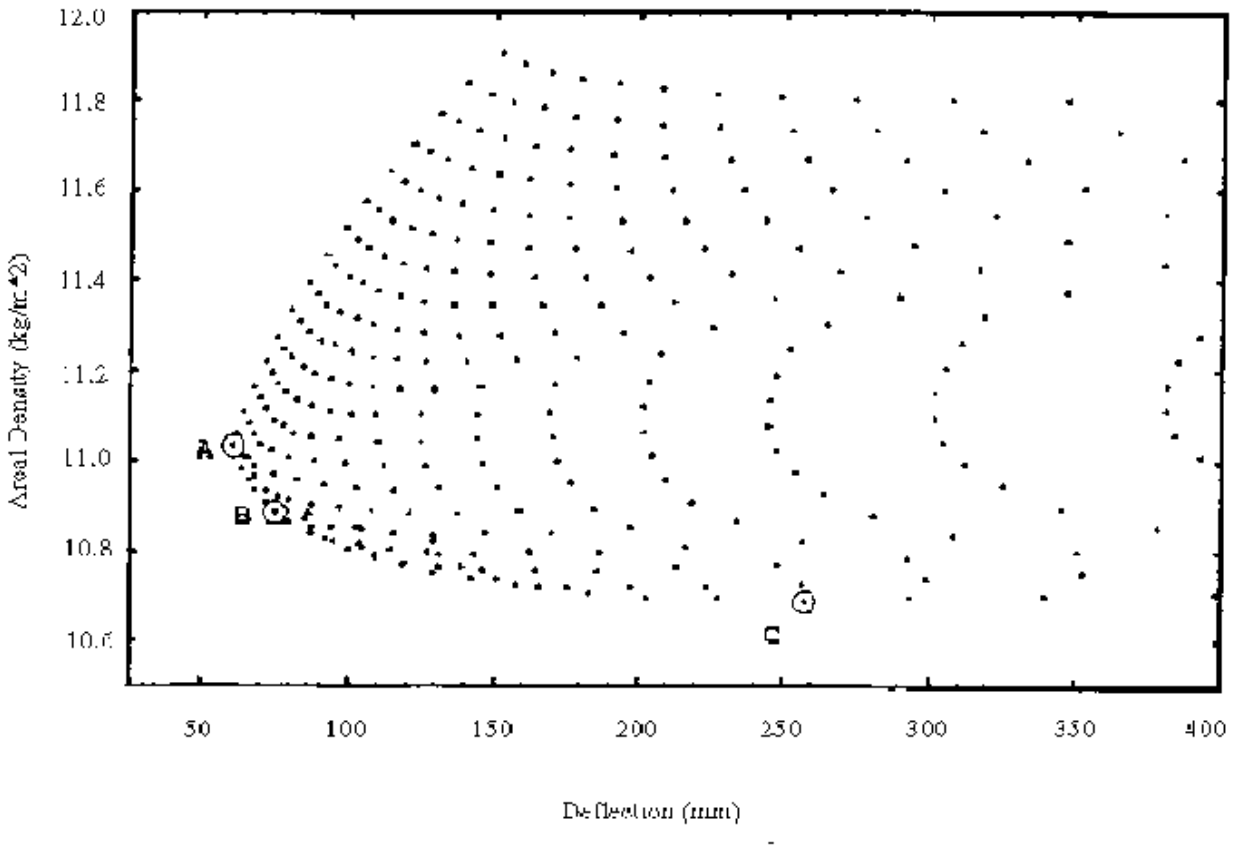


Figure 2. Diagram Showing the Set of Pareto Optimal Structures

STRUCTURES RESEARCH

During the first year of funding, a methodology for design of an optimal support structure for the testbed has been developed. Three criteria were used for development of design methodology:

(1) The structure must approximate the fundamental dynamic characteristics of a three-dimensional large structure, which in general exhibits low-frequency modes, high modal density, and global mode shape that properly reflects the coupling of the subelements of the structure;

(2) Performance of the testbed must be of comparable quality to that of an actual space telescope; and

(3) The testbed must be able to perform the essential functions needed for various system missions such as dynamic segment alignment, vibration suppression, fine pointing, tracking, and slewing.

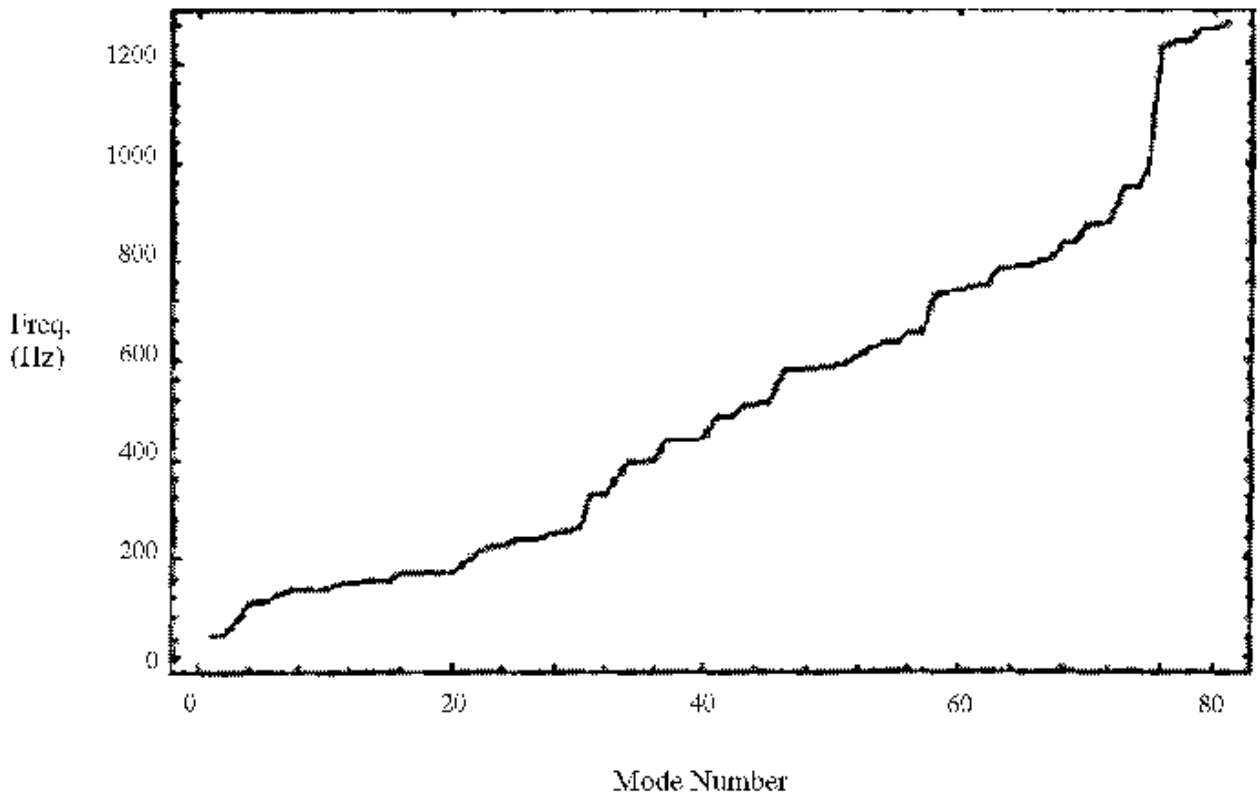
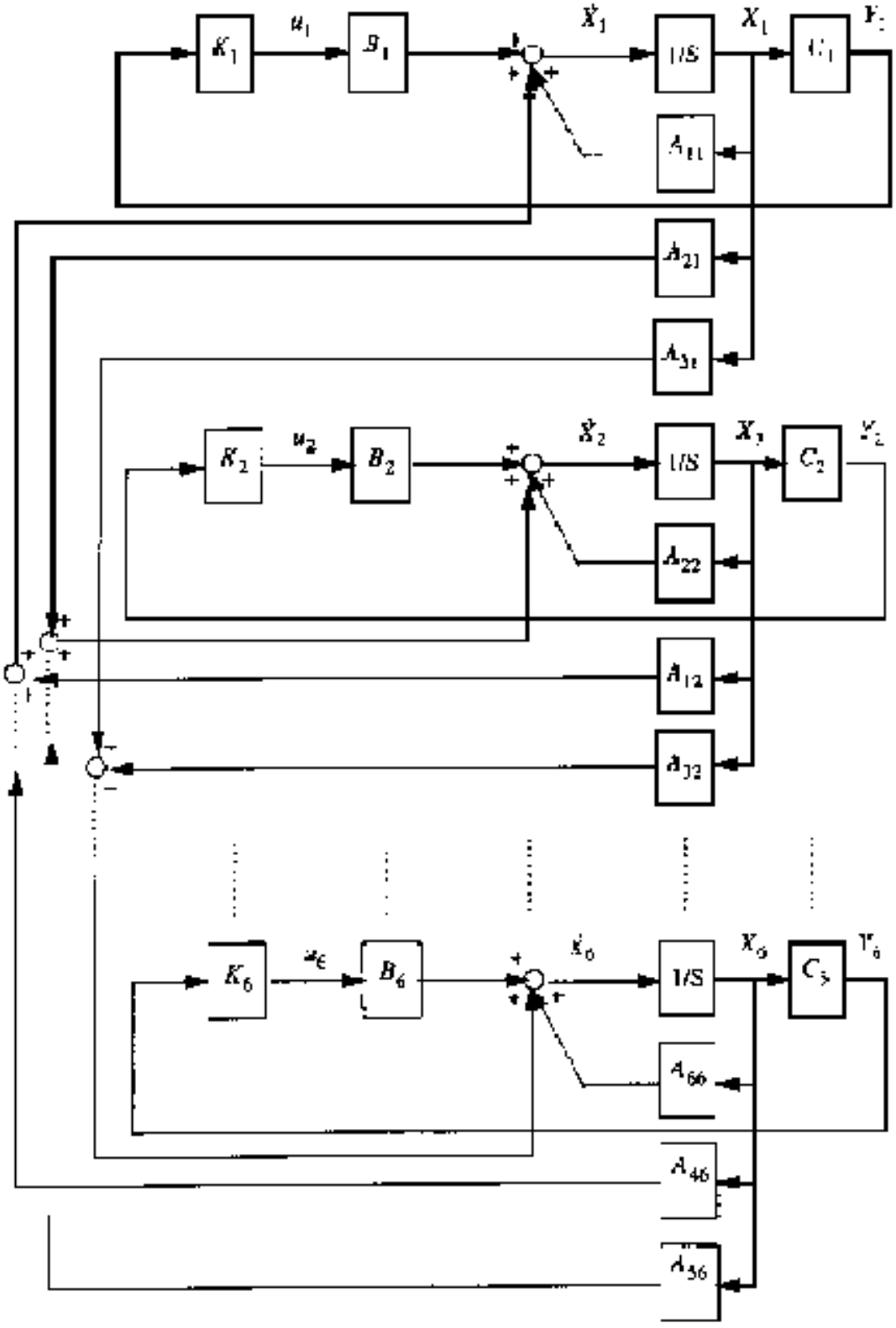


Figure 3. Frequency Histogram of Optimized Primary Structure Showing Low Fundamental Frequency and Frequency Clustering

Multicriteria optimization technique and the Pareto optimality concept were employed to obtain a class of structures that are light and rigid (Figure 2), and at the same time exhibit the same dynamic characteristics of a large flexible structure (Figure 3).


K1
u1
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C1
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A21
A31
K2
u2
B2
1/S
C2
A22
A12
A32
K6
B6
1/S
C6
A66
A46
A56

Figure 4. The Structure of the Decentralized System

CONTROL RESEARCH
The dynamic complexity and high dimensionality of large flexible structures such as the segmented reflector limit the application of conventional control strategies based on a single controller. Advanced control algorithms based on a decentralized control scheme (Figure 4) were developed using techniques such as pole placement, PID, and LQR. Criteria developed at the subsystem level along with the interaction among the subsystems were used to develop algorithms at the global level to accomplish shape control and vibration attenuation.

Neural-network based identification (Figure 5) was employed as a first step toward development of neural controllers.

The control algorithms developed were validated via computer simulations.

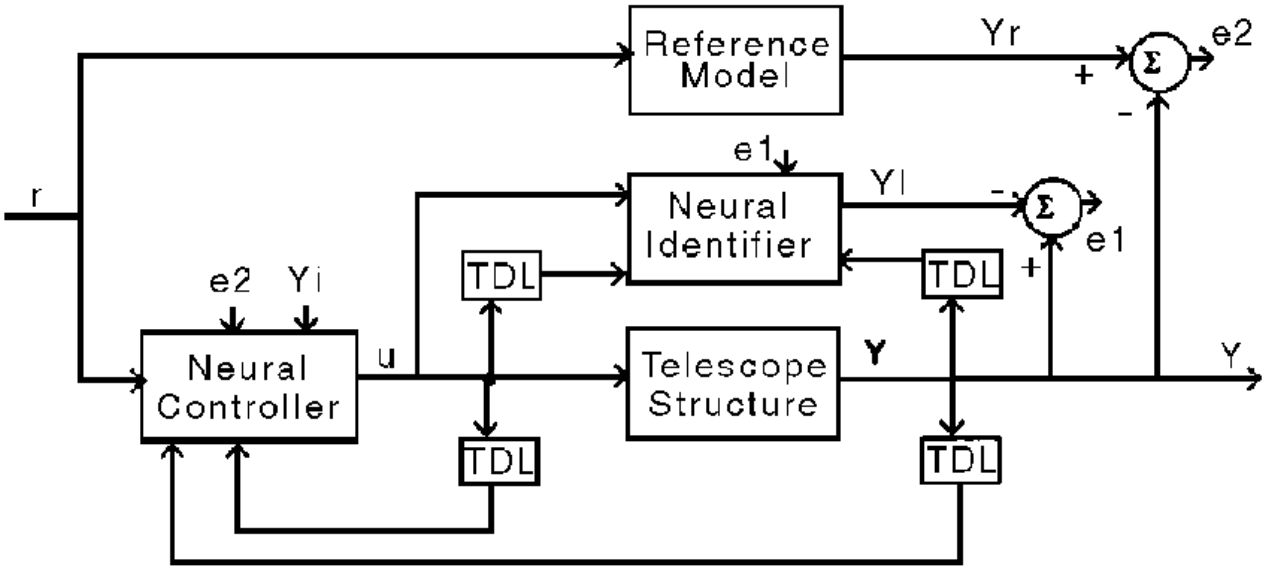

Figure 5. Control of Structure through Neural Networks

"Tunable Solid State Lasers and Optical Imaging"
Principal Investigator: Dr. Robert R. Alfano
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Date of Original Award: 1994

Report:
INTRODUCTION

The CUNY program objective is to develop new lasers, devices, and procedures that will enhance the imaging of objects imbedded in highly obscuring backgrounds. Our approach is to study broad aspects of the problem: light sources, detection techniques, image enhancement methods, computer modeling and simulation, and human visual image processing. Applications range from imaging fuel drops in a combustive mixture, an aircraft in fog, or a tumor in human tissue. Following are highlights of recent achievements.

TUNABLE SOLID-STATE LASERS

Two CUNY groups are developing tunable solid-state lasers used as light sources for analogs of imaging, and other, studies. A new class of potential host materials for analogs of chromium-doped forsterite crystals has recently been identified. Cr^{4+}-based crystals are tunable over a wider spectral range (1.2-1.7μm) than those with Cr in other valence states. The host material has the form Cr:(AM)AlO_2, where AM can be Li, Na, or K.

A step toward achieving 10mJ pulse energy for pumping a parametric oscillator has been attained. The pulse energy of a monolithic self-Q-switched laser has been increased to the 1-mJ level, while preserving the single-longitudinal and single-traverse mode operation. When the monolithic cavity is end-pumped by a 50-Watt diode laser array, the laser generates 5-ns, 0.5 mJ pulses in single-longitudinal and single-traverse mode with no transient behavior.

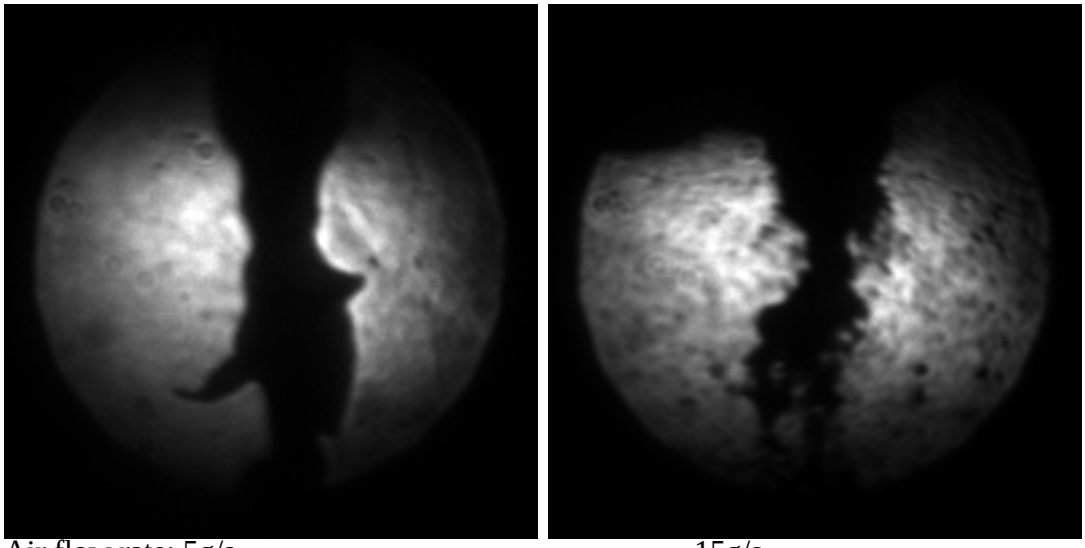
OPTICAL PROPERTIES AND PHOTON MIGRATION IN RANDOM SYSTEMS

Fluorescence imaging studies on human tissue samples have focused on finding measured intensity ratios that can be used for diagnosis. Ratios from various excitation and emission scans of a normal control population, as well as head and neck patients with premalignant or tumor tissue of the upper aerodigestive tract, were studied. These promising ratios have the capacity to discriminate normal from tumorous regions in tissue.

Optical pulse propagation through human breast tissue has been studied for thick (10 to 20 mm) and thin cancer and normal samples. Using diffusion theory, the pulse profile has been fitted to find the transport mean free path for thick breast tissue. Pulses transmitted through thin cancer and normal tissues have a broader profile, lower intensity, and later arrival time than pulses through normal tissue.

TIME-RESOLVED NEAR INFRARED OPTICAL IMAGING SYSTEM

In work done with the collaboration of a NASA Lewis Research Center group, the spatial distribution of water droplets from a simulated jet engine nozzle was measured as a function of the air and fuel speed. A picosecond Kerr-Fourier imaging system was used at a signal level of 10-10 times the incident illumination intensity. The images were analyzed and enhanced using techniques developed by other CUNY groups.



Air flow rate: 5g/s 15g/s

Figure 1. Kerr Images of a jet
Pump beam: 527nm, Probe beam: 1054nm, Water flow rate: 5 gal/hr
Mathematical Modeling Algorithms, and Computation of Images

Two inverse algorithms and a numerical method for imaging abnormalities, hidden in the turbid host media, have been developed. These algorithms had limited success and show non-unique reconstruction for layered media, and for general turbid media. The programs are better at imaging a few large inclusions rather than several small ones.

TIME RESOLVED OPTICAL IMAGING FROM TURBID MEDIA AND SPRAY
This work involves the development of feasible theoretical models and tools for image reconstruction from time-resolved optical studies. Data from sprays and turbid media are mainly supplied by the CUNY experimental group. The work has concentrated on the study of diffusion tomography. To date, this group has developed an algorithm to compute signals, designed programs for hidden 2D absorption objects in a uniform diffusion case, and designed programs for fast inversion of hidden objects.

IMAGE ENHANCING AND
CLARIFYING ALGORITHMS FOR
DETECTING OBJECTS IN TURBID MEDIA
The CUNY group responsible for processing image information, generated by other CUNY experimental teams, has implemented a program for displaying and printing imaged data at various stages of processing, developed and implemented algorithms which enhance images that can be better seen by human observers, and developed and implemented segmentation algorithms that are capable of grouping homogeneous parts of an image into units as boundaries and regions.

Optimizing Human Image Interpretation and Processing
After acquisition and initial computer processing, images are presented to a human observer for final evaluation. This work involves the preparation of an image evaluation procedure based on measures of consistency. When 2-D fluorescence images of human tissue samples were examined, it was found that the range of gray-scale variation across pixels was very small; thus, monochromatic display produces poor images. Pseudo color display appears to enhance the images greatly.

Characterization of Turbid Media
The objective is to characterize the colloidal suspensions from which image information will be extracted. This work has concentrated on characterizing droplet and bubble distributions in sonicated aqueous

environments within a Coaxial Injector Spray. The Spray is used by NASA to simulate data that will be used to predict the performance and stability of liquid propellant rocket engines.

OPTICAL MICROSCOPY IN TURBID MEDIA
Kerr-Fourier imaging techniques were used to image a test bar chart hidden by a slab of highly scattering medium. It was found that both the spatial filter and time gate improved image quality.

HIGH RESOLUTION IMAGING
USING SCANNING TUNNELING,
ATOMIC FORCE AND NEAR FIELD
OPTICAL MICROSCOPIES
Scanning tunneling microscopy (STM) and atomic force microscopy (AFM) have been used to study the effects of ion bombardment and annealing on amorphous silicon and amorphous carbon diamond-like atomic scale composite (DLASC) films. This work demonstrates DLASC hardness and wear resistance, and should be of considerable interest to NASA.

"High Performance Database Management with Application to Earth Sciences"
Principal Investigator: Dr. Naphtali Rishe
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Date of Original Award: 1994

Report: We are developing algorithms and a prototype of a high-performance Spatial Semantic Database Management System. Our system should be useful for a wide range of database applications, as well as for specialized domains such as the Earth Sciences.

Many database applications, including those for Earth Sciences, have three essential needs: (1) strong semantics embedded in the database to handle the complexity of information; (2) storage of multi-dimensional spatial, image, scientific, and other non-conventional data; and (3) very high performance to allow massive data flow. Abundant evidence demonstrates that semantic/object-oriented databases can satisfy the first two needs better than relational databases. We are currently developing a semantic/object-oriented approach that will also satisfy the high performance needs of Earth Science applications.

Our research aims to significantly improve the usability and efficiency of highly parallel database computers and machine clusters (tightly networked groups of machines). For the following reasons, our prototype database management system will have substantial advantages over current database machines.

First, inherent in the semantic database model are superior logical properties, such as friendlier and more intelligent generic user interfaces based on the stored meaning of the data; comprehensive enforcement of integrity constraints; greater flexibility; and
substantially shorter application programs. Semantic databases represent information as a collection of objects and relationships between these objects.

Additionally, the algorithms implemented in our system make it more efficient than conventional database machines. This is due in part to the system's understanding of the data's semantics and to the higher abstraction level. Our prototype system under development is highly efficient for both small and massive numbers of processors equipped with separate memories and storage devices.

Since funding for our project began on September 1, 1994, we have made progress in several areas, namely the development of theory and algorithms for database management, the design and implementation of our testbed parallel database machine, the development of our testbed applications to implement on the database machine, and the recruitment of student researchers. We have laid a solid foundation for our research and will build upon it in the years to come.

Advancements in the theoretical aspects of semantic databases have been made, including: a load balancing algorithm that takes full advantage of the organization of semantic data in our parallel semantic database machine model; an optimistic concurrency control algorithm with granularity at the level of elementary facts; a query optimization method that has comparable performance to best estimation methods in accuracy, but that does not incur runtime estimation costs; solutions to I/O problems in large database systems; new distributed algorithms for detecting generalized deadlocks; formal executable representations of system design; and methods to access spatial, scientific, and multimedia data.

We have recently begun the design and implementation of our testbed prototype parallel database machine. In order to test and evaluate our prototype, we are completing assembly of the hardware configuration in Figure 1, consisting of 12 Gbytes of hard disk space to be distributed over 4 Sun computers that will maintain our experimental databases; results will later be extrapolated to massive numbers of processors and disks. Our demonstration should be able to support several terminals retrieving data at near video speeds.

We have been collaborating with Earth Science researchers to produce semantic schemas of databases of interest to Earth Scientists. In collaboration with researchers at the Everglades National Park, we have developed a full semantic schema for observations made at the Park. We are also collaborating with researchers at the University of Miami and Goddard Space Flight Center to develop requirements for spatial data handling and testbed schemas.

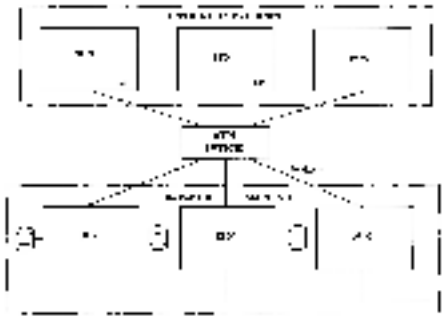

Figure 1. Testbed Prototype Parallel Database Machine Hardware Configuration

One of our research areas is the development of a simple Geographic Information System that will recover the data from the demonstration database via the ATM switch, and will display query results in a variety of standard forms, either as static images or as moving pictures, to a scientific user. These programs, written by our students, currently provide limited functionality but they do achieve near-video speeds under UNIX. We are presently able to display Ozone and Ocean Temperature data in a map form or on a static or rotating globe. The data can be observed to change in time and controls are provided to alter the mode and rate of display.

We have recruited a number of promising graduate students to work on this project and have begun training them in semantic databases, parallel processing, and spatial data handling. The faculty participating in the research have exposed students in the courses they are teaching on databases and parallel processing to the ideas behind the research being conducted by our group.

"Alliance for Nonlinear Optics"
Principal Investigator: Dr. Ronald D. Clark
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Date of Original Award: 1994

Report: The mission of the Alliance for Nonlinear Optics is to conduct the basic research needed to bring nonlinear optics technology to the point where private industry can utilize this technology for practical optical devices. The Alliance consists of seven faculty at five schools working on individual aspects of the problem in conjunction with NASA. The schools involved are: Alabama A&M University, New Mexico Highlands University, Spelman College, University of Alabama in Huntsville, and the University of Puerto Rico at Mayaguez. The areas being addressed by the group are: theoretical calculations, synthesis of new materials, material measurements, crystal growth, thin film growth, and device fabrication.

A mathematical technique has been developed by Beatriz Cardelino (Spelman College) and Moore (Marshall Space Flight Center) to predict second-order nonlinearity in organic molecules. Work is now underway to refine the technique by comparison of theoretical calculations with experimental data and extend this capability to third-order effects. Initial work will soon be undertaken to look at molecular conformational effects.

In the area of synthesis, most of the work has been concentrated on organic molecules that are thermally stable at melt temperatures. A series of dicyanovinylbenzene derivatives are being synthesized to meet this need. Work is continuing to find other stable systems with high nonlinearity. Another series of compounds under investigation is the phthalocyanines. These pigments are thermally stable, and while dark colored, they have a clear region in their spectrum at the region where third harmonic generation occurs.

The group has the ability to make EFISH measurements (at the University of Alabama in Huntsville) on solution samples, and is developing the ability to make Kurtz Powder measurements at several sites. Special equipment for spin coating and Langmuir-Blodgett film formation is also available.
Crystal growth and thin film work is underway on the dicyanovinylbenzene compounds that have been shown to be thermally stable. Thin film work is also proceeding on COANP, a known NLO compound that has proven to have unusual properties. Phthalocyanines are also being used to form Langmuir-Blodgett films. These materials have potential applications in selective sensors as well as normal optical devices.

A final mission of the project is education. Students are involved in the project at all five schools. Student backgrounds range from freshmen through graduate students and their contributions to the project are absolutely vital to its the success.

"Land Management in the Tropics and its Effects on the Global Environment"
Principal Investigator: Dr. Brad R. Weiner
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Date of Original Award: 1995

Abstract: In Puerto Rico, large areas that had previously been devoted to tropical agriculture have been allowed to revert to natural vegetation over the last several decades. Based on these changes, we use remotely-sensed images acquired over time to identify "land-use change chrono-sequences." Within these sequences we conduct several parallel studies: 1) identify plants that become dominant or decline through time; 2) compare the outcomes of different land-management strategies; 3) examine physical, chemical, and microbial changes of the soil, and the effects of those changes on surface waters; and 4) examine the organisms responsible for the release of greenhouse gases.

These data are of fundamental importance to predict how future land-use changes in the tropics may affect biology, watershed hydrology and chemistry, and the atmosphere.

LANDSCAPE-SCALE PROCESSES

During our first year, this group has constructed and verified the Geographic Information Systems (GIS) overlays for Puerto Rico that are needed for site selection and data interpretation in this project. These include Holdridge life zones, land-use, hydrography, transportation, political boundaries, and elevation (completed), and soil association types and geology (in progress). We have also inventoried and increased T.E.D.'s holdings of aerial photography and digital imagery, and we have issued purchase orders for island-wide SPOT satellite coverage.

We included an undergraduate course "Introduction to Remote Sensing" in the Environmental Sciences Program (ESP) at UPR-Rio Piedras in Spring of 1995. Other related courses that have been offered this year by the ESP include Terrain and Land-Use Analysis and Geographic Information Systems. The facilities at the ESP spatial analysis laboratory, for use by both undergraduate and graduate students, have been enhanced by the purchase of additional computers configured to run image processing and geographic information systems software.

ECOSYSTEM RECOVERY

For the first year this group focused on landscape analysis of the northeastern municipality of Luquillo because it connects the Caribbean National Forest with the coast, and is currently under high development pressure.

Overall, age since abandonment was the best predictor of stand characteristics. Woody plant density is very low during the first ten years, but increased rapidly from year 10 to 25. The number of woody species increased rapidly between stands of age 10 to 30 years and appeared to level off by 60 years, but diversity continued to increase, suggesting that these sites are dominated by a few species. We demonstrated that secondary forest can recover after abandonment of cattle pastures. Initially, recovery process is inhibited by herbs, but after woody species shade the herbs, forest re-establishes in 20 years.

ECOSYSTEM PROCESSES

Land-use changes have drastically modified the biology and probably the microbiology as well, although few studies have been done at the microbiological level, especially in tropical soils. It has been shown that soil release of greenhouse gases increases as a result of conversion of forests to pastures, so this has been an important initial topic for this group. Across land-use chrono-sequences in Puerto Rico, we are sampling soils for bacteria, greenhouse gas fluxes, nitrogen chemistry, and earthworm populations. Earthworm patterns in tropical succession are of particular interest because their population changes coincide with the soil gas flux changes. The soil microbiology is relying on advanced techniques of DNA hybridization and amplification. Other group efforts are focussed on measuring environmental and stream water quality changes associated with land-use changes in Puerto Rico. We are also examining chemical reactions and fates of greenhouse and other reactive gases with tunable dye lasers and laser fluorescence techniques.

"Research in Advanced Aeronautical Propulsion Systems (RAPS)"

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Date of Original Award: 1994

Report: Two technical tasks are proposed for RAPS. Task 1 will address development and effective use of high-temperature, lightweight titanium Metal Matrix Composite (MMC) materials to replace monolithic metallic materials used in selected aircraft gas turbine engine components. For advanced turbine engine designs to realize the potential benefits offered by titanium MMCs, design, analysis, and life-time prediction methods (inherently heavily computer dependent) must be evaluated, demonstrated, and verified for engine components made of these advanced materials. In brief, a modular, damage-tolerant MMC life-prediction system will be developed.

Task 2 will contribute to improved modeling, analysis, design, and interaction of propulsion components using advanced methods of control and simulation of fluid flows. These developments must reflect materials degradation as well as handle the difficult question of engine transients analysis in aircraft gas turbine engine control. Additionally, this task will contribute to improved engine performance goals by effectively using methods in computational fluid dynamics to simulate fluid flows through propulsion components.
Tasks 1 and 2 will provide an opportunity for UTSA RAPS faculty and graduate student teams to be in residence at host MMC Life Prediction Cooperative (LPC) companies and at NASA Lewis Research Center (LeRC) during the summers, thus ensuring full understanding of the aircraft gas turbine industry and its constraints. Additional student interaction with the RAPS project will be in an interdisciplinary advanced design class in propulsion systems for seniors and graduate students. In this manner, more students will learn the details of aircraft gas turbine engine design, and they will experience how design teams in industry and government work.

A major effort for year one was to build the necessary RAPS internal infrastructure and to utilize the necessary personnel and equipment in order to successfully accomplish the objectives of the technical tasks in years two through five. Another major effort was to establish the necessary external relationships for the NASA IRA RAPS personnel with aircraft gas turbine engine industry and the MMC LPC.

Task 1 accomplishments include an industry-defined database hierarchy that is being used to organize titanium MMC (TMC) data in M/VISION. The hierarchy and resultant database will be submitted to NASA LeRC shortly for evaluation as a working model database to be used in conjunction with structural analysis codes. Task I accomplishments further include analysis and evaluation of a model material concept for TMCs under fatigue crack growth conditions and life prediction of TMCs under low cycle fatigue.

Task 2 accomplishments include the development and design of optimal control techniques based on a newly developed class of nonarithmetic filters beneficial in detecting abrupt changes in engine time histories. Also, the potential for improving engine performance by increasing the thrust-to-weight ratios using model-based control of aircraft gas turbine engines is being pursued.
COMMUNICATIONS PROJECTS

“An Urban Collaboration for Network Connectivity and Internet Access”
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Abstract: The proposed Network Resource and Training Site (NRTS), CCNY, has extensive experience in the design and implementation of campus-wide LANs. The purpose of this proposal is to facilitate the identification and procurement of viable levels of Internet access for regional sites participating in the Institute for Climate and Planets (ICP). These resources would enhance the ability of the regional sites to capitalize on NASA-related and other existing programs for minority research and education in science and engineering.

The ICP is a collaborative effort involving the NASA Goddard Institute for Space Studies (GISS), the City University of New York (CUNY) Alliance for Minority Participation (AMP), and New York City high schools. Participants from five CUNY minority colleges (OMUs) and four NYC high schools are engaged in an evolving, hybrid research network working with GISS scientists on problems in global climate change and planetary science. A fundamental component of this program is the development of "satellite" GISS research programs on each ICP campus. This proposal is seen as an opportunity to launch these campus-based programs effectively by providing the substantial funding required for the plan, design, and implementation of the physical infrastructure requirements for campus-wide LANs and Internet access. These resources will also play a significant role in enhancing existing MSET research and education programs.

CCNY proposes to provide immediate terminal server access to regional sites to facilitate program needs and training. An outcome of this proposal will be T1 access for each of the regional sites.

General needs for the high schools will include network and application servers and software, CSU/DSU units and routers, fiber risers and high -speed switches, hubs supporting 100 users, and SNMP modules and management cards. Requirements for the colleges will be similar but will be determined more accurately from the detailed site surveys to identify corrective and integration requirements.

The proposed NRTS will provide remote network monitoring and filtering. Training and support for regional site technical staff will also be provided by augmenting CCNY's network operations and user support teams. Support will be provided on-line, by telephone help-lines, and on site where required. Internet training will also be provided both at CCNY and, with adjunct support, at the regional sites. To supplement proposal funding, planned and proposed partnerships will seek to secure in-kind contributions, donations, and discounts on materials and machines to support this extensive effort.

An outcome of this initiative will be the development of a strategic approach to network design and implementation and the integration of Internet access. Training models for both technical staff and user applications (including the use of Internet resources) will also be developed. CCNY is committed to sharing these widely within the region to assist other colleges and schools.

"Regional Network Resources
and Training Site at ECSU
(NRTS at ECSU)
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Date of Original Award: 1995

Abstract: We propose to establish a Regional NRTS to serve the Northeastern North Carolina Region and the Eastern Virginia Region. ECSU is currently the only HBCU/MI in northeastern North Carolina or eastern Virginia which has a dedicated T3 multi-way video and high speed data (25-45 Mbs) backbone, a teleconferencing classroom (NC-REN), and a video conference room.

ECSU will expand networking capabilities of its own campus to provide access to all MSET departments. This will involve installing fiber optic cable to Jimmy Jenkins Science Complex, Lane Hall, and Dixon Hall Technology buildings. Lester Hall, which houses the Mathematics and Computer Science Department, already has ATM networking and its own SunSparc mail server. A NRTS office will be established in Lester Hall where the system administrator, principal investigator, and students will work. The NRTS office staff will conduct schedule training and provide on-line and telephone support to partners.

It is our intent to include HBCU/MI partners, predominantly minority elementary and secondary schools, linkage to an industrial partner, and linkage to a NASA installation.

The NRTS at ECSU will provide network training and facilitate HBCU/MI network opportunities in research and education for MSET faculty and students, as well as for the teachers of predominantly minority-attended elementary and secondary schools in ECSU's region.

Teacher coordinators will select student Internet research teams. Hands-on exercises will be utilized by the teacher coordinators to assist students as they learn to navigate the Internet. University mentors will assist the teacher coordinators and students in constructing their own home pages on the World Wide Web, and confer with teacher coordinators on network access and usage.

ECSU will recruit 5 students in this program from our existing student population and from the pool of high school seniors. We fully expect the ethnic and gender mix of the students selected to reflect ECSU's 75% minority and 55% female student population. Each student involved in the program will be expected to maintain the qualifying 3.0 GPA, devote 20 hours each week to working in the NRTS Support Office (NSO), undertake a networking project under the mentorship of the NSO staff, and remain a full-time student carrying at least 25 hours of coursework.

Dr. Linda Hayden will serve as Principal Investigator, and Dr. Ellis Lawrence will serve as Co-I at ECSU. The combination of Drs. Hayden and Lawrence bring networking experience, NASA research experience, and project management experience to this initiative. Both are full tenured professors at ECSU and are committed to the purpose and activities of the NRTS initiative.

"Morgan State University Network Resource Training Site (NRTS)"
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Date of Original Award: 1995

Abstract: Morgan State University is a comprehensive, urban-oriented institution located in Baltimore near the city's business center. As an Historically Black University, Morgan aims to enroll a heterogeneous student body and maintain as a primary goal the education of the disadvantaged, the poor, the underrepresented, and the undereducated. Morgan offers strong undergraduate Arts and Sciences programs, Pre-professional and Professional programs, and graduate programs in a variety of disciplines.

The University has acquired a Cray J916 supercomputer as a component of NASA's Minority University Space Interdisciplinary Network (MU-SPIN) Program, interconnecting the computing facilities of the nation's HBCUs and Other Minority Universities with the NASA science network. This supercomputer will eventually provide more than 170 minority institutions direct access to high-speed computing power, while promoting awareness and usage of wide area networking in support of collaborative research among faculty, students, and NASA scientists.

Morgan's academic buildings, administrative buildings and student residences are all connected via fiber cable. The University operates several dedicated laboratories, with handicapped access, for instruction and research. The labs utilize the considerable expertise of the MSU faculty to conduct science, engineering and mathematics (SEM) outreach programs to local elementary, middle, and high schools. Some labs are equipped with distance learning capability, utilizing state-of-the-art multimedia equipment. The labs also support the many training and research collaborations with other local institutions such as Johns Hopkins University and the University of Maryland, in addition to governmental agencies such as NASA, the National Science Foundation, and the Department of Energy.

The University's technological capabilities provide the foundation of the technical plan for the Morgan NRTS. The program will provide outreach teacher training to area colleges, as well as to elementary, middle, and high schools. The Morgan NRTS will bring teachers, students, and in some cases parents to the MSU campus for hands-on training during the summer and will provide the technical resources to enable participating schools to continue this training within their own institutional environments.

The Internet and computer resources at Morgan State University will provide the training environment in which teachers may learn how to use Gopher, Mosaic, and the World Wide Web. Pre-college teachers will be educated on how to access information from the Internet so that it can be incorporated into their classroom experiences. The Morgan NRTS summer workshop for area pre-college teachers will provide those with basic and intermediate knowledge of computer use with an opportunity for advanced training.

During a one-month period over the summer, selected students from the participating pre-college schools will also have an opportunity to be introduced to computer, Internet, and e-mail capabilities. Math and science courses, geared to reinforce skills and generate interest in the sciences, will bolster the computer exposure. At the end of the summer camp, students will have a basic understanding of the equipment and experience in accessing and manipulating the new technology.

Training for college-level instructors will include advanced search and access techniques on the Internet as well as an overview of Internet mechanics. Overall, this group of participants will be provided broad exposure to the Internet, how it functions, and how to use it most effectively and efficiently.

"Establishment of a NASA Southwest Regional Network Resources and Training Site"
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Date of Original Award: 1995

Abstract: This proposal presents a plan for establishment of a NASA-sponsored Regional at Prairie View A&M University. The goal is to create a high-speed digital network consisting of data and video channels linking a series of remote sites. This network will result in creation of a virtual university for sharing of resources by all participants in the project. Additionally, the network will provide for enhancement of the learning experience for the traditional learning community (K- 12 and college students) serviced by the participants as well as providing access for involvement of the larger adult community. The proposed area

of impact includes the states of Texas, New Mexico, and Oklahoma. Participants in this collaborative effort include Prairie View A&M University (Prairie View, Texas), Navajo Community College (Shiprock, New Mexico), Central Consolidated School District (Shiprock, New Mexico), Wiley College (Marshall, Texas), Texas College (Tyler, Texas), Jarvis Christian College (Hawkins, Texas), Paul Quinn College (Dallas and Waco, Texas), Houston Tilloston College (Austin, Texas), Langston University (Langston, Oklahoma), Waller Independent School District (Waller, Texas), and the Hempstead Independent School District (Hempstead, Texas). Each of these institutions is either an Historically Black College or University, a Native American serving institution, or one which serves a majority population of underrepresented participants in science, mathematics, and/or engineering.

A five-year development plan will be implemented in several phases. First-year activities will include extension of the existing College of Education Local Area Network at Prairie View A&M University (PVAMU) to include the Departments of Biology, Chemistry, Mathematics, and Physics. The first year will also include installation of a link to Shiprock, New Mexico to provide access to Navajo Community College and to the Central Consolidated School District. The existing link to the Waller Independent School District will be expanded to include the Roberts Road Middle School and the Holleman Elementary School. The feasibility of adding a school from the Hempstead Independent School District will be investigated.

A PVAMU Task Force composed of the Dean of the Graduate School and Research, Dean of the College of Education, Dean of the College of Arts and Sciences, and the Department Head of each of the PVAMU science departments will be formed to provide coordination of network enhancements at PVAMU. A management team composed of at least one representative from each of the participating entities presented above will be established to provide guidance and direction for implementation of the virtual campus concept. An invitation to participate on this team will be extended to a member of the Minority University Space Interdisciplinary Network (MU-SPIN) office as well as to a representative from a major computer manufacturer.

An implementation plan will be developed to bring all sites on-line within three years. Plans for staff and curriculum development activities utilizing the network will be formed.

"Center for Network Resources and Training"
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Abstract: South Carolina State University (SCSU) proposes to establish a Center for Network Resources and Training (CNRT) under the NASA Institutional Research Award (IRA) Program administered by its Minority University Research and Education Division. The successful implementation of this center will initially provide direct Internet access training and services to five HBCU's and four predominantly minority-attended elementary and secondary (PM-AES) schools. By the completion of this project, it is anticipated that services will be expanded to schools and other organizations outside the original partnership. Additionally, the CNRT will expand the utilization of the Internet for SCSU's math, science, engineering and technology (MSET) departments to include research enhancement, faculty and staff development, curriculum innovations, and opportunities for increased student use.

The technical plan is to establish local and wide area networks capable of supporting the University's MSET departments and to acquire and maintain the necessary components to establish T1 connectivity between the CNRT and the nine regional sites. The educational plan is geared to provide training to the

faculty, staff, and students of SCSU as well as the collaborating partners in the use of the Internet to facilitate scholarly research and innovative education with a focus in the areas of MSET. Through this, the faculty will access global databases for up-to-date information in their fields of research. Also, they will be engaged in innovative curriculum design, the use of state-of-the-art multimedia technology, and object oriented programming software for instruction and development of resource material for the Internet.

The diversified activities of the center will be managed by a team approach, with the PI reporting directly to the Vice President for Academic Affairs. South Carolina State University will fully commit its resources to the center and its mission to acquire the most advanced technology in the field of information exchange thereby facilitating faculty and student development and strengthening its community based outreach programs. In order to accomplish these tasks, South Carolina State University will strongly support the objectives of CNRT. Specifically, SCSU will provide $1,767,128 in cost sharing for CNRT.

SCSU has established a strong partnership base with entities in academia, industry, and government, including MIT, Hughes Aircraft, Bell South, and Sun Belt Net. These partnerships will assist during the planning and implementation stages. Also, these partners will ensure that the CNRT will continue to operate long after the initial five-year award period. In addition to the above cooperative/industrial collaborations, Stanback Planetarium, the NASA Regional Teacher Resource Center (RTRC), the S.C. Space Grant Consortium (NASA), and the Bamberg-Calhoun- Orangeburg Math/Science Hub will be able to utilize the CNRT to significantly increase the dissemination of information available through the Internet.

"NASA/TSU Network Resources and Training Site"
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Date of Original Award: 1995

Abstract: Tennessee State University (TSU) realizes the opportunity afforded by the NASA NRTS program for making the Internet accessible and usable by HBCU's/OMU's and public schools with a predominately minority student body. This program provides the impetus for TSU to enhance its own network and use its experience and knowledge to assist other institutions in establishing an Internet presence.

TSU currently has staff and faculty that are experienced in establishing networks, organizing the infrastructure (both technical and administrative) to support networks, and training users. Furthermore, TSU has a history of working with other local HBCU's and public schools on projects of mutual benefit.

In the preparation of this proposal, cooperating institutions (including public secondary schools, private colleges, and public institutions of higher education) have been contacted. All of these institutions have shown great interest in participating in the NASA/TSU NRTS.

Outside the academic arena, TSU has been successful in gaining the cooperation of an industrial partner who will assist in some areas of network monitoring. This is especially helpful in reducing the cost in establishing the NASA/TSU NRTS, in addition to providing some skilled personnel in network monitoring who would not otherwise be available.

Marshall Space Flight Center (MSFC) has also agreed to be a cooperative partner in several areas. MSFC will review the networking plan as it develops and provide design critiques. For cooperating institutions that are unable to get immediate T1 Internet connections, MSFC has agreed to make accounts available on one of their servers via

800 numbers. This greatly enhances the effort to get the cooperating institutions connected to the Internet as quickly as possible.

This cooperative effort between public schools, private institutions, industry, NASA, and TSU affords TSU the opportunity to not only improve itself, but also to assist many other institutions who have not had the resources to take advantage of the vast amount of information available over the Internet. At the end of this project, TSU will have helped to establish a large base of trained Internet users and network managers who can help each other as well as assist other Internet newcomers in getting started.

"University of Texas at
El Paso Network Resources
and Training Site"
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Date of Original Award: 1995

Abstract: We propose to establish an NRTS that will substantially increase access to the Internet and the use of Internet resources by faculty and students in Science, Mathematics, and Engineering Technology (SMET) departments. The proposal will also enhance linkages with institutions in the greater El Paso area (E1 Paso Community College and New Mexico State University), a selected number of middle schools in the E1 Paso area (all of which are predominantly minority attended), one HBCU (North Carolina A&T), and one OMU (University of Texas Pan American). It will increase their Internet use and support existing and future collaborations between these schools, UTEP, and federal agencies such as NASA and NSF.

Most elementary and secondary schools in the E1 Paso area do not have Internet access for their students and have very limited access for their teachers. We propose to target three schools and provide them with high-speed Internet access, help them establish a local area network, provide training to teachers and students, provide them access to the network resource offices at UTEP, and create forums in these schools that involve both faculty and students at UTEP.

Currently, UTEP has a T1 connection to the Internet. But only about half of the SMET departments have their own LAN, and very few SMET faculty outside of the Computer Science Department use the Internet for teaching and research. In order to improve this situation, we propose to:

- provide server (www, gopher) access to all SMET faculty and selected students at UTEP, where they can put materials related to their interests, including research and teaching;

- designate one faculty member from each SMET department as the network liaison for each year, providing him/her with one month's summer salary so that (s)he can receive adequate training in using network resources for teaching and research and disseminate this information to others in his/her department;

- employ a student in each SMET department to help the network liaison and the network support staff (if any) in the department and to hold seminars in the department on network applicability and usage;

- provide adequate training to at least one network support staff person in each SMET department to assist in installing and maintaining servers, browsers, and other Internet software;

- provide Internet access to all students, with quick training on how to access the vast resources available through the Internet;

- create innovative electronic forums that build interaction between students and professors within different departments of UTEP, and with faculty and students of the participating institutions and schools; and

- establish three network resource offices, consisting of a network management and operations office to help and train entities in UTEP and its collaborators in setting up LANs and connecting them to the Internet, an application installation support office to help and train entities in UTEP and its collaborators with the installation of application programs, and an application users support office.

  UTEP commits to provide: 1) 20% release time for the PI to supervise the proposed NRTS; 2) several students to work on this project; 3) training facilities at its Multimedia center; and 4) additional Internet gateways for students and faculty.

Most of the participating institutions mentioned in the proposal have Internet access. We propose to provide those that do not have Internet access with high-speed links to the Internet. For each of the institutions we propose to:

- provide training to at least one person;

- provide server access to interested faculty in these institutions, and help them create documents relevant to their research and teaching;

- provide electronic access for students, faculty and staff to the network resource offices at UTEP;
- substantially improve the coordination related to ongoing joint projects through the use of the Internet; and

- take advantage of Internet connectivity to establish further joint projects.

FACULTY AWARDS FOR RESEARCH (FAR)

NASA's Faculty Awards for Research (FAR) program seeks to provide NASA with those resources necessary for mission completion while developing a diverse NASA-sponsored research community made up of institutions with significant underrepresented minority enrollments. Thus, the FAR program supports faculty-driven research at Historically Black Colleges and Universities (HBCUs) and Other Minority Universities (OMUs), that is relevant to NASA Strategic Enterprises as described in the NASA Strategic Plan. The research areas of strategic interest to NASA are; Mission to Planet Earth; Aeronautics; Human Exploration and Development of Space; Scientific Research; and Space Technology. Participation in FAR is open to tenure-track underrepresented minority and disabled faculty of HBCUs and OMUs that offer graduate degrees in engineering, mathematics, or science disciplines.

As a result of participating in this program, underrepresented minority and disabled faculty principal investigators will contribute directly to NASA research and support the development of underrepresented minority and disabled student researchers. Opportunities for participation in the Agency's mainstream research will expand as recipients research capabilities are enhanced through interaction with NASA researchers and facilities. Additionally, the pool of underrepresented minority and disabled students with research experience and interest in pursuing advanced degrees in the fields of science, engineering, and mathematics will increase through faculty support. One hundred and forty-seven students were involved in FAR research projects during the current funding year: 39 at the Ph.D. level; 58 at the M.S. level; and 50 at the B.S. level. Sixty five percent were male and 35% were female. Fifty percent were members of underrepresented ethnic minority groups: 23% at the Ph.D. level; 59% at the M.S. level; and 62% at the B.S. level.

Forty-one awards were made between 1992 and 1995. It is anticipated that additional awards will be made in 1996. Brief reports and/or abstracts from programs receiving funds during 1995 follow.

RESEARCH AREA: AERONAUTICAL ENGINEERING

"Nonlinear Dynamic Analysis of Mistuned Bladed-Disk Assemblies"
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Date of Original Award: 1993

Report: Recent concerns for lightweight, efficient, high-bypass propulsion applications in aircraft and energy-efficient power generation systems have led to modern axial-flow compressors with flexible cantilevered airfoils of high aspect ratio. Unfortunately, in part-speed operating conditions, these turbomachines may experience severe vibration of the rotor blades, including high cycle fatigue and eventual structural failure. Such failures are frequently caused by aeroelastic phenomena associated with flutter and forced response. The intent of our current direction of research has been to enhance the current state of turbomachinery aeroelasticity by providing a robust predictor model for aeromechanical analysis and design of bladed-disk components subjected to multiple restrictions, including axial-flow compressors. Specifically, our ongoing research focuses on obtaining optimum designs for axial-flow compressor bladed-disk components subjected to multiple restrictions, including axial vibration and forced response, kinematic coupling, stall flutter, dynamic and steady-state centrifugal stresses, passive dampling mechanisms (e.g. viscous, hysteretic, dry friction) to offset aero-dampling instabilities, strength integrity of the fibrous composite mold construction, and blade mistuning. What follows are further details of our ongoing research sponsored under Grant No.NAG3-1571.

One focus of our research has been to provide structural dynamacists and aeroelasticians with a fast and versatile approximate model for iterative redesign experimentation of blade-disk assembly forced response over a wide range of geometrical and material property parameters. In our approach, the structural dynamics of the bladed-disk assembly is derived from a three-dimensional (3-D) energy based Ritz model [1] incorporating nonuniformities in blade chord, blade-disk thickness distribution, blade twist and skewness, and blade camber. The
3-D Ritz model also accommodates laminated orthotopic materials, and contains complete centrifugal and gyroscopic acceleration effects. The 3-D energy-based Ritz model provides good approximate upper bound results for the structural dynamics in a fraction of the cost required for a comparable finite-element analysis.

Linking this structural model with recently developed aerodynamic models for nonuniform flow in blade passages is the focus of our ongoing research efforts. This linkage will allow for cost efficient parameter studies of the aeromechanical characteristics of axial flow compressor components as a number of global parameters are varies, such as blade taper and aspect ratio, radius ratio, solidity (blade gap-to-chord ratio), number of blades, flow nonuniformities due to inlet distortion and upstream flow obstructions, and aerodynamic and mechanical dampling. The forced response analysis developed in this work includes three components: flow defects (e.g., inlet distortion, wakes, pressure disturbances from adjacent rows), unsteady blade loads (i.e., aerodynamic dampling and forcing functions), and blade response.

The efficiency of the model and the ease with the parameters may be changed will allow engine designers freedom to explore various design options quickly and at relatively low cost. The accumulated findings of this research will also provide additional insight into optimal (structural and aerodynamic) tailoring as an intentional manufacturing procedure for reducing blade flutter and coupled response mechanisms.

An important aeromechanical design concern of shroudless, wide-chord transonic blading used in multi-spool bypass aeroengines is the elimination of kinematically coupled modes of axial vibration and flutter. For such blades the lowest coupled flex-torsion modes may exhibit variations with rotation speed that may be described as dangerously close to integral order resonant and stall flutter boundaries. Some aeromechanical sources of flex-torsion mode coupling are nonuniform blade planform and variable thickness, blade cross-sectional asymmetry, cyclic blade loads due to angular velocity and momentum or due to upstream flow obstructions, blade manufacturing imperfections, and fibrous composite construction. The latter source, which is a recent development for transonic blading employed in the cold stream fan and front compressor stages of modern, energy-efficient, high-bypass turbofans, is the vantage point of recently completed work [2]. It is postulated that optimum protection against coupled axial vibration and stall flutter of laminated composite blading is achievable through a proper selection of laminate design parameters without altering the blade's aerodynamic profile characteristics. The intent here is to optimally identify permissible angle-ply stacking sequences and orientation angles to alleviate integral order resonant and stall flutter characteristics, to control twist-flex vibratory displacements, and to ensure the mechanical strength integrity of the fibrous composite blade construction under steady centrifugal tension and gas bending stresses. Design data and Campbell diagrams are presented for first approximations of typical blades employed in modern bypass aeroengines. Results summarize optimum design histories of ply lay-ups and non-dimensional constraints (i.e., reduced frequencies, twist-flex vibratory displacements, and principal stress limits of composite layers at the disk wheel). The theoretical findings of this paper suggests to structural dynamacists and aeroelasticians an efficient design strategy for passive restriction of coupled mode flutter and integral order resonant behavior of laminated composite transonic fan and compressor blades.

1.Turbomachinery Aerodynamics, Whittle Laboratory, University of Cambridge Program for Industry, University of Cambridge Board of Continuing Education, Cambridge, England, June 20-24, 1994

2. 39th and 40th ASME International Gas Turbine and Aeroengine Congress and Expositions, The Hague, Den Haag, The Netherlands, June 10-13, 1994, Houston Exposition Center, Houston, TX, June 5-8, 1995.

"Studies in Shock-Wave Interactions with Homogeneous and Isotropic Turbulence"
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Date of Original Award: 1993

Report: The development of future aircraft and rotorcraft demands a better physical understanding of shock wave interactions with turbulent flows. A better understanding of the physics involved may lead to improvements in calculation methods with turbulence modeling, which currently are based on incompressible turbulence concepts.

The interaction of a travelling normal shock wave with decaying, grid-generated turbulence has been studied using time-resolved measurements of pressure, temperature, and velocity in the large-scale shock tube research facility of CCNY. The size of this facility provides a platform for high spatial resolution measurements of turbulence.

In the present investigation the effects of shock strength and mesh size of the turbulence-generating grid on the flow interactions were addressed independently from each other. Different initial levels of velocity fluctuations and length scales were used before the interaction, and their modification after the interaction was studied in detail. The present results verified a proposed power law decay of turbulent Mach number in the range of 0.01 to 0.1. Mach number fluctuations depend on the mean Mach number and on the grid. Coarse grids have different behaviors than fine grids. It was also found that the amplification of longitudinal velocity fluctuations also depends on the Mach number of the incoming flow and the grid size.

"Turbulent Premixed Methane-Air Combustion: Emissions, Characteristics, and Modeling"
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Date of Original Award: 1995

Abstract: This study proposes to enhance the understanding of turbulent premixed methane-air combustion while at the same time developing the background, experience, and facilities for future participation in NASA's Microgravity Combustion Program. An understanding of turbulent combustion of natural gas or methane is essential, since the characteristic dimensions and flow rates of most industrial equipment are often large enough for flows to be turbulent. In spite of the many prior studies on methane-air combustion, much still remains to be done and understood. The effects of chlorinated hydrocarbons, pressure, injection orientation, flow rate, and fuel/air ratio on the emissions and flame characteristics are not well understood. The current prediction models are also not reliable.

The emissions, flame shape, velocity, and temperature distribution from turbulent methane-air combustion at various conditions of flow rate, injection configuration, pressure, and CH4/air ratio will be experimentally determined. The effects of the presence of chlorinated hydrocarbons on the efficiency and characteristics of the combustion will also be ascertained. A mechanistic model that will explain and improve the reliability of prediction methods for turbulent methane-air combustion will be developed.

The proposed study will develop the background, experience, and facilities that will enable Clark Atlanta University (CAU), an historically black college and university (HBCU), to compete and join the growing list of institutions undertaking studies in microgravity combustion. It will also help produce minority scientists and engineers trained to assist NASA and other agencies/industries in the area of combustion.
RESEARCH AREA: ASTRONAUTICAL ENGINEERING

"Dynamics of Variable
Mass Systems"
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Date of Original Award: 1993

Report:
INTRODUCTION / RESEARCH OBJECTIVES
The main aim of this research project is to explore in depth the dynamic behavior of bodies of different shapes that suffer substantial mass variation as they move around in space. Investigations of the dynamic behavior of Engineering Systems are usually conducted in several phases. First, an adequate mathematical model is developed. This usually involves an idealization of the system (in terms of rigid bodies, springs, fluids, etc.), followed by the generation of the equations of motion through the use of one or more of the principles of mechanics. Attempts are then made to solve these equations of motion using any of several possible techniques. The preference is to obtain closed-form solutions; but because this is seldom possible for equations of any level of complexity, other options are often explored, including numerical methods and approximate methods commonly used in nonlinear mechanics. Finally, the mathematical solutions are translated into useful practical information, in terms of the physics of the problem, about the behavior of the system. Sometimes the investigations are also validated by relevant experiments. This project includes all four phases described above, and thus involves theoretical/analytical investigations as well as some numerical and experimental work.

RESEARCH OUTCOMES AND
PROGRESS TO DATE
So far, we have made progress in a number of areas. First, we conducted an exhaustive literature survey, and derived the full equations governing both the translational and rotational motions of general variable mass systems. By comparing these equations with those for a rigid body, the contributions of mass variation to the behavior of the system are explored for various realistic scenarios. The equations of attitude motion were then specialized to the case of axisymmetric variable mass systems in free flight, and solved in closed form. We found that the free attitude motions of axisymmetric variable mass systems differ markedly from those of rigid bodies of similar shape. Although an axisymmetric rigid body in free flight maintains a constant spin rate throughout, variable mass systems can spin up, spin down, or maintain a constant spin rate. The magnitude of the transverse angular velocity can also grow or decay with time, depending on how the system's moments of inertia vary. For spinning rockets, the desire is to have any transverse angular velocity components introduced by transient disturbances decay rapidly with time. In order for this to occur, the transverse moment of inertia should not be allowed to vary much. For rockets, variation in inertia is a result of fuel depletion. It is thus possible to influence the attitude motion to one's advantage by making judicious choices for the mass, shape, location, and depletion strategy for the rocket's propellant. This work establishes general criteria for growth or decay of spin rate and lateral angular speed, and crystallizes these results into practical design criteria for rocket-type systems.

"Automated Space Robotics for Satellite Rescue"

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Date of Original Award: 1992

Report: The idea of on-orbit servicing is not new—in the mid-1970s to early 1980s, NASA's Marshall Space Flight Center, with the aid of Martin Marietta and Grumman, developed the "Tumbling Satellite Retrieval" concept. This work was an outgrowth of work that began with the Skylab demise. A 1992 study conducted jointly by NASA and INTEC concluded that satellite servicing may be feasible under appropriate conditions. The "service" vehicle used in this NASA/INTEC study was the Shuttle.

To date, the work completed in this project is motivated by the need for a national policy on on-orbit servicing/satellite rescue, not the ad hoc policy now in place. The primary focus of the present research is to develop rendezvous/capture techniques that are (i) autonomous (i.e., the human operator is not present, thereby, reducing the cost) and (ii) capable of servicing a wide range of disabled satellites.

In the development of such a national policy, the issue of capture and stabilization of tumbling spacecraft must be addressed. For a rescue mission involving a tumbling spacecraft, it may be advantageous to have a rescue vehicle that is compact and "rigid" during the rendezvous/capture phase. After capture, passive stabilization techniques could be utilized as an efficient means of detumbling the system of rescue vehicle and captured spacecraft. Since the rescue vehicle is initially compact and "rigid," significant passive stabilization through energy dissipation can be achieved through the deployment of flexible appendages. Once stabilization is accomplished, retraction of the appendages before maneuvering the system to its final destination may also prove advantageous. It is therefore of paramount interest that a study of the effect(s) of appendage deployment/retraction on the attitude stability of a spacecraft be conducted. Of particular interest is the effect(s) of appendage retraction, since if this process is destabilizing, passive stabilization as proposed would not be useful. These studies have been conducted and have produced positive results. Via non-dimensional parameters, stability bounds have been developed.

One of the more critical issues of a rescue/service mission is the process of rendezvous and docking. To address this issue, a two-phased proportional navigation scheme has been developed for the case of two rigid bodies engaged in a planar rendezvous/docking maneuver. In the study, the target vehicle is non-maneuvering, but does have constant nonzero angular and linear velocities. Under the conditions, it is shown that rendezvous and docking is possible (this result has never been previously accomplished). Analytical solutions are obtained leading to relationships between the transverse navigation constant for the second phase of the maneuver. A proof-of-concept demonstration is being pursued. This demonstration would be conducted at Marshall Space flight Center. Once the proof-of-concept is demonstrated, the analysis will be extended to the three-dimensional case.

"A Study of the Fluid Mechanics
of Reacting Flows in Selected Aerospace Propulsion Devices"
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Report: Many reacting flow problems are of interest to the aerospace community. These include the ionization of plasmas in electromagnetic and electrothermal space thrusters and the mixture and burning of gases and/or liquids in conventional air breathing engines. This research project addresses some of these topics specifically, and then formulates a paramaterized generic mixing/reaction problem, which contains the flows of interest as a subset. This generic problem can be used to identify similarities and differences between well-understood flows and problems that are more poorly understood.

The research project starts with one-dimensional reacting flows. Many of these flow situations can be solved analytically. Those flows that are too complicated for analytic solution will instead be simulated on computers. Relaxation methods and simple Runge-Kutta space marching methods are being compared to spectral method solutions for computer simulation of the one-dimensional flows. Considerations for stiff sets of equations often encountered in reacting flows will have to be made. Reaction models will have to be adapted to work with the spectral flow solver. Two dimensional analysis will begin in year two.

The first flows being addressed will be the ionizing flows in electromagnetic and electrothermal accelerators, starting with atomic propellant injection and ending with molecular propellant injection. The plasma analogy to lean blowout in combustion is currently being analyzed. In support of this analysis, the reaction rate models to be used have been further developed and documented. In particular, in year one, compact ionization models that include the effects of multiple excited states have been explored. These compact models allow accurate collisional rates to be included in computational models efficiently, and also allow for predictions of the emission radiation spectrum.
The next flow considered is that found in electrothermal/chemical hybrids. The final specific problem to be looked at is the chemical combustion problem. The remaining part of the research will be the formulation of a generic mixing/reacting flow problem and its simulation on the computer. All of the flows of interest will be included as parameterized regimes of the generic problem.

The problem of reacting flows in aerospace propulsion devices is crucial in the design of a new generation of more efficient, cleaner operating engines. This work is applicable from piston engines through gas turbine engines, to future supersonic combustion engines, to chemical and electric rockets. There are also many industrial applications for reacting flow research.

Three undergraduate students work on this research project each academic term. These students assist Dr. Sheppard in collecting references, programming, and in setting up and maintaining the workstation used for the computations required in this project.
RESEARCH AREA: BIOLOGICAL SCIENCES

“Monoclonal Antibodies Directed Against Surface Molecules of Multicell Spheroids”
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Report: Multicell spheroids (MCS) are highly organized, three-dimensional multicellular structures that exhibit many of the characteristics of in vivo tissues (Figure l). They also provide a functional assay for surface adhesion molecules. In brief, MCS combine the relevance of organized tissues with the accuracy of in vitro methodology.

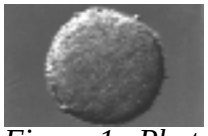

Figure 1. Photomicrograph of MCS at 5 Days (125X)

MCS are formed via a two-step process mediated by cell-cell interactions (Figure 2). In the first step, single cells in suspension collide and adhere to form loose aggregates. In the second step, aggregates compact into MCS capable of three-dimensional growth.

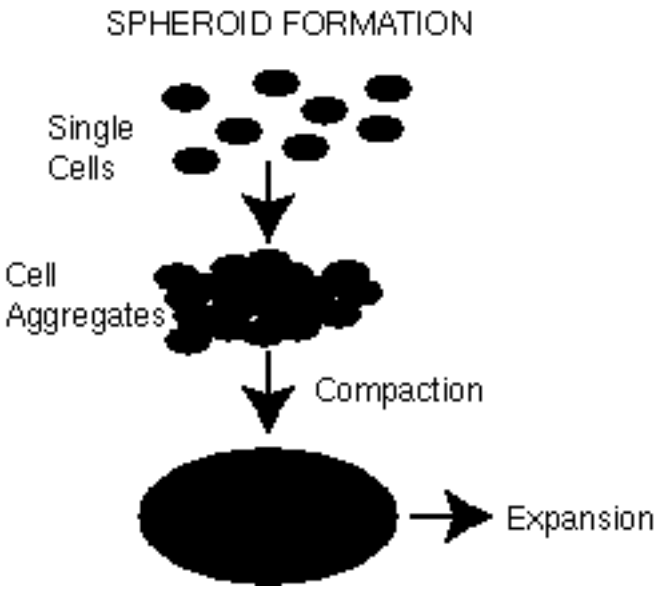

Figure 2. Two-step Model of MCS formation.

Figure 3. Immunofluorescent Staining of SV40-Transformed WI38 Fibroblasts with MAb MTS 1.2 (100X)

The objectives of this project are twofold: First, to generate a panel of monoclonal antibodies (MAbs) directed against surface molecules of MCS, and second to utilize this panel to characterize the cell-cell interactions that mediate MCS formation. The results obtained will provide a base of information that will be used in comparative studies of cell-cell interactions in simulated hypergravity and microgravity environments.

This project also has the potential to yield important materials (i.e., reagents) which could be useful in the diagnosis and/or treatment of certain human disorders. Moreover, this grant provides support for the training of graduates and undergraduates; thus, it also assists in developing a pool of future scientists with research interests that are relevant to NASA' s mission.
A panel of MAbs that bind specifically to points of cell-cell contact on MCS has been generated (Figure 3). A number of MAbs from this panel have been characterized using biological functional assays. Preliminary results show that some of these MAbs may block MCS formation. A radiolabeled centrifugal assay to quantify the strength of cell-cell adhesion has been developed. Studies to determine the effects of MAbs on cell-cell interactions in different mammalian cell lines are in progress.

RESEARCH AREA: CHEMICAL ENGINEERING

"Experimental and Analytical Studies of Capillary-Pumped Loop Heat Pipes"

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Report: The capillary-pumped loop (CPL) heat pipe is a two-phase flow device that is capable of transferring large amounts of energy over long distances. The circulation of the working fluid results from capillary forces developed in the wicking material. Although the potential of the CPL for space applications has been demonstrated in ground and flight tests, there is the need to address fundamental thermal and fluid issues.

The primary objective of this work is a consistent experimental study of the CPL with ammonia as the working fluid. The parametric study includes variations in the length and diameters of the vapor and liquid transport lines, the effects of uniform and nonuniform heating of the evaporator, and the start-up characteristics for a range of operating conditions. A secondary objective is the development of a model and the validation of same using experimental data.

A schematic of the test facility designed and built for the experimental studies is shown in Figure 1. The main components include a reservoir, an evaporator pump, a condenser unit consisting of a Neslab Model CFT-75D chiller and a Parker dual heat transfer coil, and a flow metering section.
Provisions are made for measurements of temperatures and pressure differences. The difficulty of finding a commercially available flow meter that is compatible with ammonia and provides accurate data prompted an in-house development of a method to meter the flow. The flow rate of ammonia is deduced from pressure drop across a tube length, with corrections for differences in density and viscosity between ammonia and water; the latter is used to obtain base line flow rate and pressure drop data over the same tube length. An ancillary facility, to be used for the charging of the test facility with ammonia, was also designed and built.

Figure 1. Schematic of CPL test Facility

For the experiments, the goal was to test an evaporator pump that is a replicate of that under consideration for possible future application on the Earth Observation System (EOS). The results are expected to be of relevance to NASA's CPL technology program. For this reason, extensive consultations were made with Swales & Associates, Inc. (a primary NASA contractor on the CPL technology) during acquisition and construction of the test facility. To meet the design specifications, the two evaporators for this work are fabricated by Swales & Associates, Inc. (Lanham, Maryland).

"Statistical Sensor Validation in Life Support Systems"
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Report: A major objective of this project is the development of statistical techniques that validate and improve measured variables in space closed-loop life support systems (CLLSS). We have made significant advances in statistically modeling measurements in the case of redundant sensors. This approach involves a sophisticated use of confidence intervals and its performance has been demonstrated in an extensive Monte Carlo Simulation study. The next step in this program is to develop methods that will give accurate performance under less restrictive conditions. In addition, we plan to evaluate this method using real data provided by NASA Ames.
Research is also being conducted that addresses some of the statistical issues surrounding the benefits and drawbacks of artificial neural networks (ANN). This work is important because a major component of this research involves investigating the merits of a combined ANN sensor validation technique. One drawback of ANN in the modeling of data is their tendency to overfit to a data set, i.e., to model not just the underlying structure, but also the random error in the data. This can result in an inappropriate model selection, and can make the model inadequate at prediction. To deal with this drawback, ANN researchers use existing statistical model discrimination techniques or create new discrimination methods to determine the correct ANN model. However, because one can seldom be confident of what the true model is in real-world applications, there is no way of telling whether or not the model discrimination technique is choosing the optimal model for that data. Consequently, there has been little or no testing of the ability of some of these techniques in ANN applications to see how they are really performing. A considerable amount of our effort has been spent on an extensive simulation study to determine the "best" modal structure.

The techniques that were evaluated were the F test, Akaike's Information Criterion (AIC), Mallows' Cp, Schwarz's Bayesian Criterion (SBC), Data Splitting (DS), and Mean Squared Error (MSE). Some of the conclusions are as follows: 1) changing the replications or experimental error variance had little effect on the different techniques; 2) MSE performed poorly; 3) Cp and AIC gave similar results, and performed well, but did not perform as well as the F test; 4) the F test and a Data Splitting criterion called Mean Squared Prediction Error performed similarly and generally performed better than other techniques; 5) SBC performed well in most situations; and 6) although none of these techniques performed well in all cases, in most situations they did a respectable job at model discrimination. For representative results of these conclusions see Tables 1, 2, 3, and 4.

Model		% of Correct Selections of True # of Nodes								
Inputs	Nodes	MSE	$F_{0.01}$	$F_{0.05}$	$F_{0.10}$	AIC	C_p	SBC	SSP	MSP
3	1	76.0	100.0	97.0	95.0	95.0	95.0	100.0	70.0	97.0
4	1	39.0	99.0	97.0	94.0	91.0	92.0	100.0	60.0	95.0
4	2	55.0	100.0	87.0	79.0	79.0	82.0	100.0	84.0	95.0
5	1	10.0	97.0	92.0	89.0	85.0	88.0	100.0	73.0	95.0
5	2	39.0	100.0	100.0	99.0	97.0	92.0	100.0	69.0	85.0
5	3	26.0	73.0	69.0	60.0	54.0	66.0	9.0	62.0	57.0
6	1	11.0	98.0	88.0	83.0	83.0	86.0	100.0	79.0	91.0
6	3	10.0	90.0	73.0	64.0	57.0	67.0	100.0	75.0	92.0
6	3	38.0	97.0	88.0	79.0	83.0	86.0	0.0	80.0	99.0
6	4	0.0	7.0	0.0	0.0	0.0	0.0	40.0	23.0	35.0

TABLE 1

Model		% of Correct Selections of True # of Nodes								
Inputs	Nodes	MSE	$F_{0.01}$	$F_{0.05}$	$F_{0.10}$	AIC	C_p	SBC	SSP	MSP
3	1	84.0	100.0	97.0	95.0	95.0	95.0	100.0	58.0	92.0
4	1	30.0	100.0	98.0	96.0	92.0	92.0	100.0	66.0	93.0
4	2	57.0	100.0	93.0	86.0	88.0	90.0	100.0	68.0	90.0
5	1	18.0	99.0	94.0	91.0	83.0	84.0	100.0	68.0	91.0
5	2	37.0	100.0	100.0	100.0	92.0	93.0	100.0	63.0	89.0
5	3	20.0	65.0	49.0	38.0	41.0	44.0	35.0	64.0	68.0
6	1	9.0	95.0	88.0	82.0	81.0	82.0	100.0	65.0	89.0
6	2	10.0	85.0	70.0	57.0	66.0	66.0	100.0	66.0	86.0
6	3	45.0	97.0	93.0	86.0	92.0	93.0	0.0	75.0	93.0
6	4	0.0	0.0	0.0	0.0	0.0	0.0	40.0	13.0	19.0

TABLE 2

Model		% of Correct Selections of True # of Nodes								
Inputs	Nodes	MSE	$F_{0.01}$	$F_{0.05}$	$F_{0.10}$	AIC	C_p	SBC	SSP	MSP
3	1	72.0	99.0	98.0	95.0	94.0	95.0	89.0	75.0	98.0
4	1	39.0	100.0	96.0	88.0	83.0	87.0	100.0	75.0	95.0
4	2	48.0	97.0	87.0	81.0	80.0	83.0	100.0	79.0	95.0
5	1	19.0	98.0	92.0	88.0	83.0	83.0	100.0	84.0	99.0
5	2	33.0	100.0	95.0	90.0	83.0	86.0	100.0	75.0	95.0
5	3	23.0	6.0	12.0	20.0	16.0	15.0	0.0	14.0	4.0
6	1	5.0	98.0	96.0	91.0	92.0	92.0	100.0	82.0	98.0
6	2	12.0	98.0	93.0	87.0	83.0	84.0	100.0	80.0	98.0
6	3	17.0	96.0	86.0	73.0	78.0	81.0	61.0	80.0	87.0
6	4	36.0	5.0	15.0	20.0	18.0	15.0	0.0	14.0	2.0

TABLE 3

Model		% of Correct Selections of True # of Nodes								
Inputs	Nodes	MSE	$F_{0.01}$	$F_{0.05}$	$F_{0.10}$	AIC	C_p	SBC	SSP	MSP
3	1	78.0	100.0	99.0	98.0	97.0	98.0	100.0	71.0	91.0
4	1	42.0	100.0	97.0	90.0	90.0	92.0	100.0	69.0	93.0
4	2	56.0	96.0	90.0	81.0	84.0	87.0	100.0	78.0	93.0
5	1	14.0	97.0	92.0	89.0	83.0	85.0	100.0	74.0	97.0
5	2	40.0	99.0	98.0	95.0	90.0	91.0	100.0	69.0	90.0
5	3	32.0	10.0	20.0	27.0	23.0	23.0	0.0	23.0	13.0
6	1	7.0	98.0	92.0	86.0	82.0	83.0	100.0	62.0	90.0
6	2	15.0	97.0	91.0	85.0	81.0	81.0	100.0	78.0	95.0
6	3	17.0	96.0	85.0	79.0	79.0	79.0	94.0	67.0	86.0
6	4	23.0	5.0	14.0	20.0	14.0	13.0	0.0	24.0	12.0

TABLE 4

"Optimal Rate Concept Acquisition for Classification
of Remotely Sensed Spatial Data and Propulsion Test Data"
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Report: The National Aeronautics and Space Administration (NASA) has collected, and will continue to collect, vast amounts of remotely sensed spatial data and propulsion test data. Although images can be interpreted visually, the sheer volume of the data prohibits strictly human processing. In addition, because computers can distinguish many more levels of information than humans can, computers have the potential to do a better job. Image processing is the manipulation and interpretation of digital images using a computer. One of the image-processing tasks involves classification, the process of assigning the pixels of an image (i.e., the most elemental component of the image, sometimes called a raster) to one of several land-cover classes or thematic categories. This technique provides a quantitative method for automating the identification of features in a scene.

The main objective of this project is to investigate the use of Artificial Intelligence (AI) expert system technology for the classification task. In particular, a machine learning technique, which combines the version space method for concept acquisition and the genetic algorithm technique for optimization, has been implemented and tested. This technique, called optimal rate concept acquisition, not only produces descriptions of classes, but also suggests the best kinds of example raw data to use for training the classification system.

Confusion matrices, like the one shown in Table 1, provide information about the accuracy of classifiers. The main diagonal of each matrix represents the portion of each class that is classified correctly. A perfect classification would produce the identity matrix. Table 1 indicates that the version space classifier correctly classified 97.61 % of 1,048,576 pixels in a test image. The accuracy rate was comparable to a neural network classifier (97.36%) over the same data. However, the version space classifier learned its classification rules after processing only the first 336 instances from a test set of 25,000 samples.

"Monitoring Software Through Integrity Constraints"
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Abstract: Although technology has made major advances over the last twenty years, software engineering has not kept pace. Software tools are needed to aid developers who are creating large, complex software systems that require deep and diverse application-specific knowledge that must be communicated to personnel with a variety of backgrounds.

One approach to capturing some of this knowledge is through integrity constraints that state the conditions that data or objects of a program must satisfy. Unfortunately, executable languages do not provide support for integrity constraints. Although some nonexecutable specification languages provide constructs for constraint specification, constraints are typically embedded within the code of the program, given as annotations, or discussed in documentation. Proving that constraints hold in a large, complex system becomes almost an impossible task. In executable languages, no automatic facility is provided to ensure that constraints are not violated.

Toward this end, the goal of the proposed research is to expand the syntax and semantics of a high-level, executable language to incorporate integrity constraint specification, constraint reasoning, and constraint satisfaction. Other objectives of the research are to develop a methodology for using this facility to its fullest capability and to involve both undergraduate and graduate minority citizens in research. The research includes defining the syntax and formal semantics for constraint specification and satisfaction in the high-level language BagL using denotational semantics, extending the language's interpreter to support integrity constraint specification and satisfaction, and developing a mechanism for reasoning about the constraints.

A varied collection of requirements will be used to define a method for capturing, organizing, and specifying relevant knowledge about the integrity constraints and context of the system, in addition to generating executable specifications which can be used to test the implementation and the approach.

0.9518	0.0326	0.0000	0.0000	0.0156
0.0472	0.9450	0.0000	0.0078	0.0000
0.0000	0.0000	1.0000	0.0000	0.0000
0.0000	0.0020	0.0000	0.9884	0.0096
0.0000	0.0000	0.0000	0.0074	0.9926

Table 1. Confusion Matrix for Version Space Classifier

"RASTA: A Reactive Assistant for Scientific and Technical Analysis"
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Report: Software agents are computer programs that assist people in performing tasks such as sorting electronic mail, aggregating keystroke sequences, database mining, etc. From a human perspective, however, assistance is more than performing a task. It implies a complex interaction with behavioral expectations that shift according to the situation. Sometimes people expect an assistant to follow instructions without question while at other times an assistant should be highly interactive, engaging, and possibly challenging.

The Reactive Assistant for Scientific and Technical Analysis (RASTA) Project's intent is to apply artificial intelligence and cognitive science to the problem of developing a software agent that helps scientific investigators analyze and explore scientific data. Its purpose is to provide assistance to users of the Linked Windows Interactive Data System (LinkWinds) under development at NASA's Jet Propulsion Laboratory. LinkWinds allows people to explore large multivariate data sets rapidly and interactively. RASTA is a situated computational agent whose reactive, potentially interactive behavior results when scientific analysis knowledge is integrated with "perceptions" of LinkWinds data analysis tool selection and usage.

The Project's research has resulted in a novel theory of computational agency and a new distributed reinforcement learning model.

The theory of computational agency is modeled in a software system called LinkAge (LinkWinds Agent). In LinkAge, the software agent explores a behavior space bounded by learning, communicating, and planning. By using a neural network to learn data analysis tool selection and usage patterns, the agent assumes assistance roles characterized by regions in the space. At one end of the behavioral continuum the agent acts as a servant by passively performing selected tasks without comment. At the opposite end of the spectrum, the agent reactively devises and executes plans to communicate with a scientific investigator in a simplified natural language (English). The result is a software agent that can serve as a reference guide, a data analysis tool, or an interactive observer, as the situation requires.

The distributed reinforcement learning model (DRLM) is a framework for multiple computational agents with limited perceptual horizons to share experiences, learn tasks, and demonstrate collaborative behavior. DRLM consists of a hidden task model that addresses the problem of perceptual aliasing among heterogeneous agents, a composite state model that accounts for the effects of task interdependencies on action policies, and a distributed Q-learning subsystem for updating the merit of task actions. A distributed Q-learning architecture that embodies DRLM allows LinkWinds data analysis tools selected by a scientific investigator to share their data analysis experiences and support the scientific analysis process. The data analysis tools serve as subagents that collaboratively inform the agent so that it can hypothesize the state of the scientific analysis process without asking the scientific investigator.

"A Computer-Based Tool for Evaluating Graphical User Interfaces"

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Date of Original Award: 1993

Report: The user interface is the component of a software system that connects two very complex systems: humans and computers. Each of these two systems impose certain requirements on the final product. The user is the judge of the usability and utility of the system; the computer software and hardware are the tools with which the interface is constructed. Mistakes are sometimes made in designing and developing user interfaces because the designers and developers have limited knowledge about human performance (e.g., problem-solving, decision-making, planning, and reasoning). Even those trained in user interface design make mistakes because they are unable to address all of the known requirements and constraints on design. Evaluation of the user interface is therefore a critical phase of the user interface development process.

The main goal of this research is the development of a computer-based tool for objectively evaluating graphical user interfaces. The research is organized into three objectives. The first objective was the development of an embedded evaluation capability to evaluate the adequacy of a graphical user interface based on a user's performance. The second objective was the development of an expert system to assist in the design and evaluation of user interfaces based upon rules and guidelines. The last objective is the development of a theoretically predictive model to evaluate display layout quality of graphical interfaces.

A Graphical User Interface Evaluation Tool (GUIET) was developed to assist designers in the process of evaluation. This tool was enhanced to include a Generic (Rule-Based) Training System (GETS). The notation, which was developed for evaluating a user's interaction with a system, was modified in order to provide the user feedback on how to use the system more effectively.

An Expert Advice System on Graphical User Interface Design and Evaluation (EASGUIDE) has been developed to assist the designer of a system. The major components of the software include a database and a knowledge base. EASGUIDE provides the user with information on a variety of topics through direct manipulation. It presents information on when a particular interface object should be used, and the advantages and disadvantages of various interaction styles. EASGUIDE automatically formulates the queries necessary to retrieve information from the database and displays it to the user. The knowledge base, along with the expert system, provide design advice on topics including appropriate background and foreground colors, fonts, when to use pop-up menus versus pull-down menus, and how to color-code different statuses.

"Next Generation Methods for Image Data Compression"
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Date of Original Award: 1992

Report: Visual information in digital form is playing an increasingly important role in our society today as well as in the scientific community. Digital images and image sequences are appearing everywhere. These images, which involve a tremendous volume of data, are typically transmitted from one location to another and eventually stored on disk or tape for recall at a later time. Due to the large amount of data inherent in a digital image (typically millions of bits), image compression is very important for economy and efficiency. Image compression allows a digital image to be represented with only a fraction of the original number of bits. This allows lmany more images to be stored on disk and enables images to be transmitted at a much faster rate.

Image compression algorithms of this type suffer loss in reproduction quality as the bit rate is lowered. In this research project, we examined this problem and developed new approaches and techniques. Among these techniques and contributions are "jointly optimized subband image coding," "conditional entropy constrained residual vector quantization," "adaptive FIR and IIR filter banks for image compression," and "adaptive entropy constrained RVQ."

The results of this work are very positive. For the popular test image "Lena," the techniques developed here produce among the best PSNR results ever reported. More interesting, however, is that for special classes of images, such as computer tomography (CT) images, infra-red images, and various earth science images, the new techniques often eclipse all others in performance by a significant margin.

Figures 1 and 2 are given as an illustration. They show a comparison of one of our methods (the jointly optimized subband coder, which we call SBRVQ) with the new international standard compression algorithm, JPEG. An original test image "Kevin" was compressed 80 to 1 and decompressed using both the subband method and the JPEG standard. The improvement in performance is both obvious and significant. We expect that subband coding technology, of the type that we have introduced, will be important in the future.

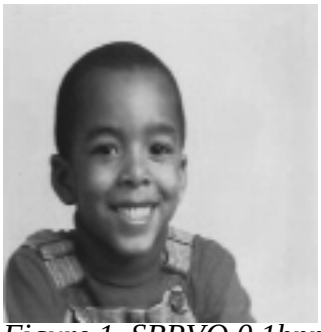

Figure 1. SBRVQ 0.1bpp "Kevin"

Figure 2. JPEG 0.1bpp "Kevin"
both figures 512 x 512

"Development of Massively Parallel Algorithms for Group
and Graph Computations in Quasicrystal Analysis"
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Report: In 1984 Schectman et. al. reported finding specimens of a rapidly quenched alloy with approximate composition MnAl6 that exhibited icosahedral diffraction symmetry. These substances were dubbed "quasicrystals" since they exhibited fivefold symmetry in three-dimensional space, and their importance in the development of new metals and glasses is well recognized. The process of determining the structure of a quasicrystalline substance is called quasicrystallography and it is based upon standard methods of crystallography. Crystallogra-phy for macromolecules (proteins and viruses) is already computationally quite intensive, and parallel computing is essential to further progress in this area. The main objective of this project is the development of fast parallel algorithms for solving crystalline and quasicrystalline structures. Our unique approach involves the integration of traditional crystallographic methods with new methods from discrete mathematics and computer science for working with algebraic groups and graphs and parallel algorithms to implement those methods. Our work has had three major foci —1) the development of parallel algorithms for performing searches on large group and graph structures, 2) the development of parallel algorithms for standard crystallographic techniques, and 3) development of new methods for quasicrystallography.

Parallel algorithms have been developed for executing large combinatorial searches involving symmetry and they were successfully applied to the problem of classifying the C60 structures. Subsequently, work was completed on the construction of permutation representations for large matrix groups.

Parallel algorithms and implementations on a number of architectures (Connection Machine, MasPar MP-1, and DEC Alpha Cluster) have been developed for various crystallographic computations including crystallographic FFTs, triplet invariant generation, and phase estimation. A new method has been developed that utilizes symmetry and hashing to dramatically reduce the amount of storage required for triplet generation and phasing, thus permitting larger structures to be solved.

The development of new methods for quasicrystallography involves understanding the fundamental computations of quasicrystallography and the possible roles that symmetry may play. Our efforts have focused on: 1) the analysis of (quasi)crystallographic computations in both direct and Fourier space, 2) the analysis of computations in a mixed direct/Fourier space utilizing the Zak transform, and 3) the derivation of algebraic relationships that lead to improved parallel algorithms.
In conjunction with our European collaborators, we have successfully applied our algorithms to the solution of a small number of protein molecules.

RESEARCH AREA: ELECTRICAL ENGINEERING

"Image Compression Based on Incomplete and Overcomplete Subband Decompositions"
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Report: One goal of this project is to develop and evaluate optimal reconstruction systems for arbitrary multirate filterbank decompositions, a technique that has applications in image compression. Based on Optimal Recovery (OR) theory, a technique to design constrained-length Finite Impulse Response (FIR) synthesis filters has been developed and applied in the context of subband image compression. The nature of the superiority of these constrained-length OR FIR filters has been demonstrated, as has been the reduced sensitivity to the effect of additive quantization errors on the subband samples. Strategies for choosing useful overcomplete subband analysis filters in subband image coding have also been identified.

When transmitting images over data channels such as those from a deep-space probe, image compression must be done with the available, uncorrupted data. A linear, optimal procedure to reconstruct from incomplete subband data has been developed and evaluated to deal with such a problem. The degree to which easier reconstruction is possible when the available data is correlated with the missing data is illustrated and used to suggest its use when data loss is expected. The use of overcomplete transforms in subband coding is therefore of use in these cases.

Research is also being done on other methods of compression for space applications. The High-Speed Pyramid (HSP) image compression technique has been studied and advanced in every aspect, including: analysis of the decorrelation potential of the HSP transform, analysis of the impact of the use of Zero-Tree (ZT) coding after quantization, and generalization of the ZT scheme by replacing it with the use of Vector Quantization (VQ) across the levels of the pyramid hierarchy. A major goal is also to extend the method while preserving its major benefits.

The HSP is being evaluated and adapted for optimized performance on specific classes of NASA images including optical navigational images, synthetic aperture radar images, and planetary images. At this time, a block/scene-adaptive bit allocation strategy that uses a segmentation of the image has proven to be very promising.

"Computational Field
Simulation on Massively
Parallel Supercomputers"
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Date of Original Award: 1993

Report: Parallel computing has been increasingly important in computational physics and engineering. In this research we are considering the development of a number of computational linear algebra algorithms for use in electromagnetics and semi-
conductor device simulation. These algorithms are targeted specifically to a Multiple-Instruction-Multiple-Data (MIMD) parallel computing platform.
All research now being performed is targeting the Cray YMP and Cray T3D MPP parallel computers. The actual machines that are being used are located at New Mexico State University and at the Jet Propulsion Laboratory. The following addresses three related research areas that are currently being sponsored by NASA.

DEVELOPMENT OF DIRECT SOLVERS FOR LARGE SPARSE SYSTEMS OF EQUATIONS
The solution of large sparse systems of equations is important in many areas of computational physics and electrical engineering. This research considers two classes of sparse systems. The first class includes systems that are numerically symmetric and positive definite. The second class includes systems that are structurally symmetric and indefinite.

A general-purpose, scalable algorithm has been developed for the direct solution of sparse, linear systems of equations. Problems of up to order 600,000 have been considered on a 256 node Cray T3D. The algorithm utilizes a one-way dissection decomposition of the graph representing the system. This decomposition results in a border-block diagonal structure to the system, which can be solved on a parallel computer. Currently the algorithm utilizes 3n-3 processors for the solution of a given problem, where n is the number of subdomains used in the decomposition. The systems currently being studied are generated by the finite-element discretization of Poisson's equations or the vector Helmholtz wave equation for electromagnetic phenomena. Figure 1 shows the unscaled speedup for a three-dimensional problem with 387,321 unknowns. Figure 2 shows the scaled speedup for several two-dimensional finite element problems.

SOLUTIONS OF THE NON-LINEAR
DRIFT-DIFFUSION EQUATIONS
The governing drift-diffusion equations for semiconductor devices are highly nonlinear. The equations are discretized using finite differences. The resulting set of non-linear algebraic equations is solved using the Newton-Raphson method in conjunction with either a direct LU solver or Conjugate Gradient Squared Iterative solver. The Cray T3D data parallel programming model has been used to implement the numerical solution. Figure 3 shows the unscaled speedup for a one micron FET device discretized with 32768 unknowns.

DEVELOPMENT OF MULTIGRID
ALGORITHMS FOR SOLVING
NONLINEAR ELLIPTIC PROBLEMS
A multigrid code for solving linear elliptic problems has been implemented on the Cray T3D. The code uses Jacobi iteration using a standard multigrid V-cycle accelerator. The code is used for both two-dimensional and three-dimensional problems. Figure 4 shows the unscaled speedup for two different two-

dimensional problems. Figure 5 shows the unscaled speedup for two different three-dimensional problems.

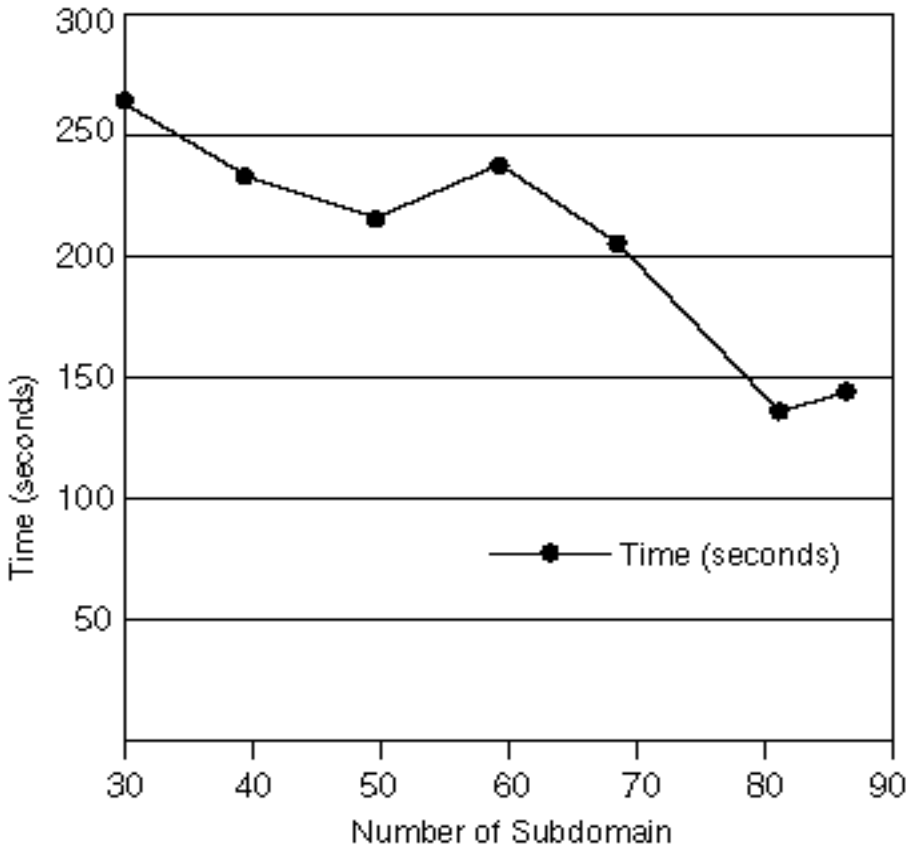

Figure 1. Unscaled timings for 3D problem with 387,321 Unknowns

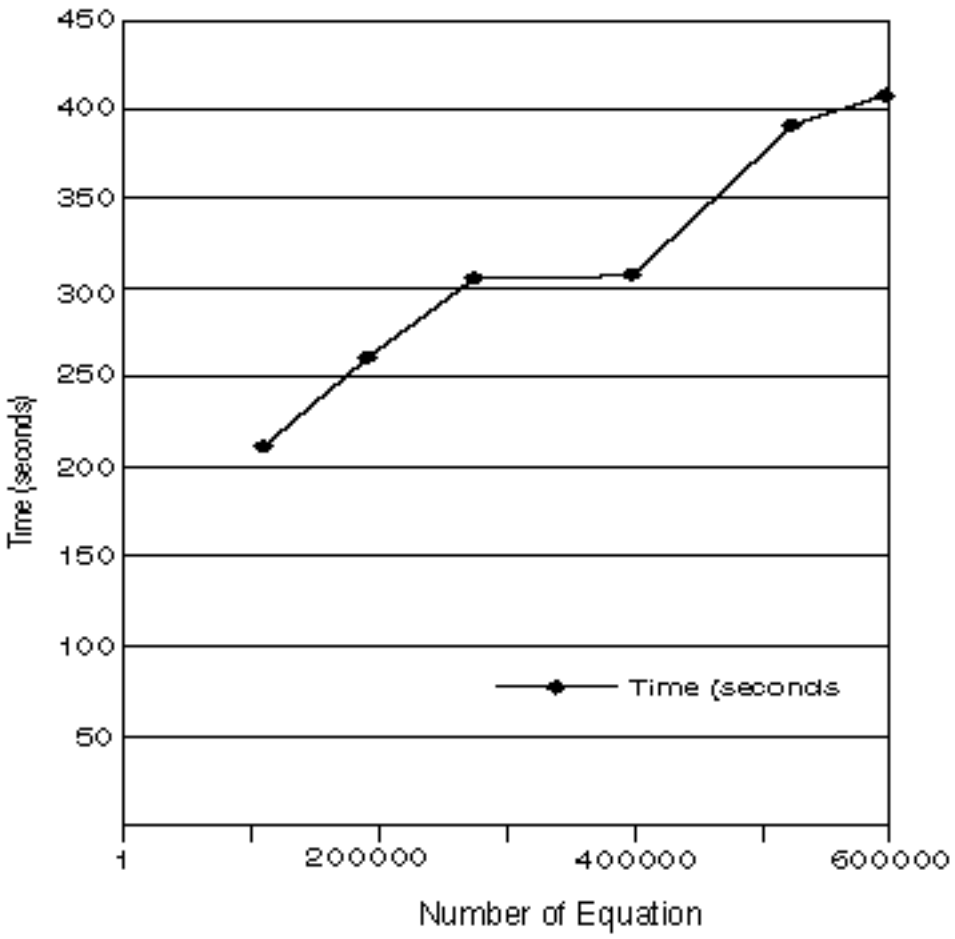

Figure 2. Scaled Timings for 2-D Problem

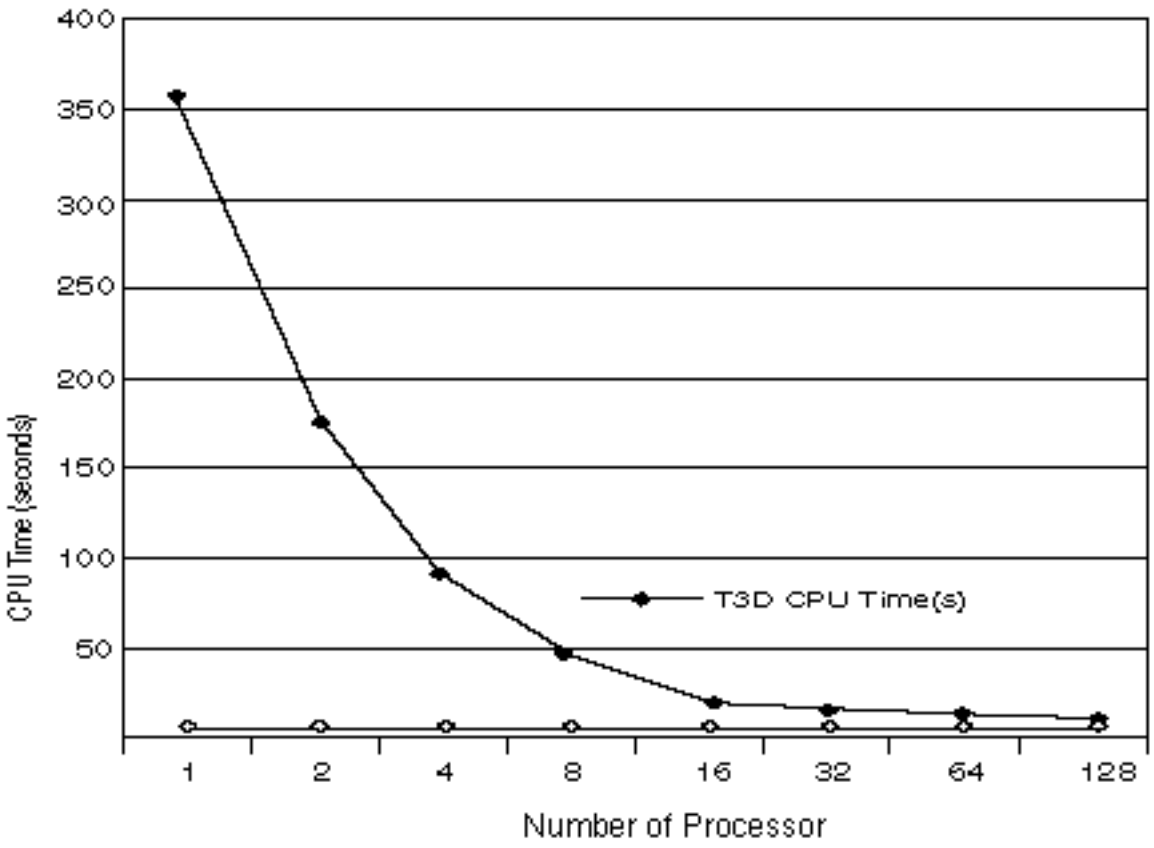

Figure 3. Unscaled Speedup for FET on T3D with 32,768 Unknowns

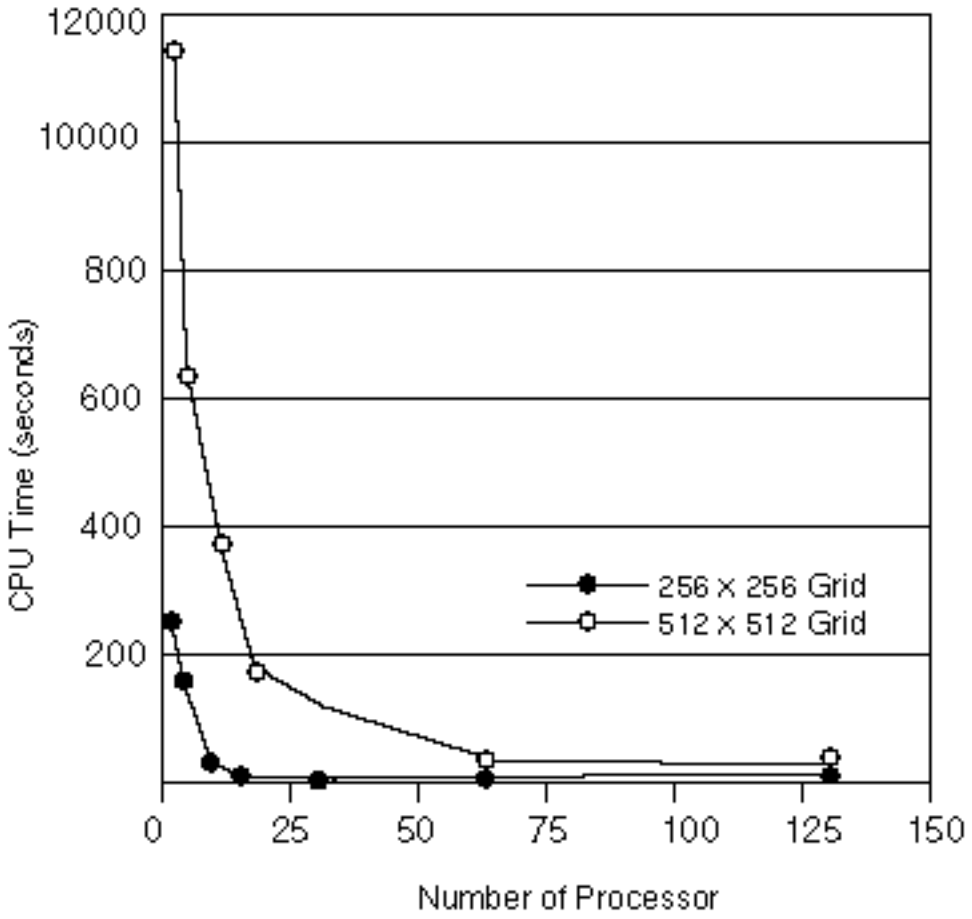

Figure 4. Unscaled Speedup for 2D Multigrid

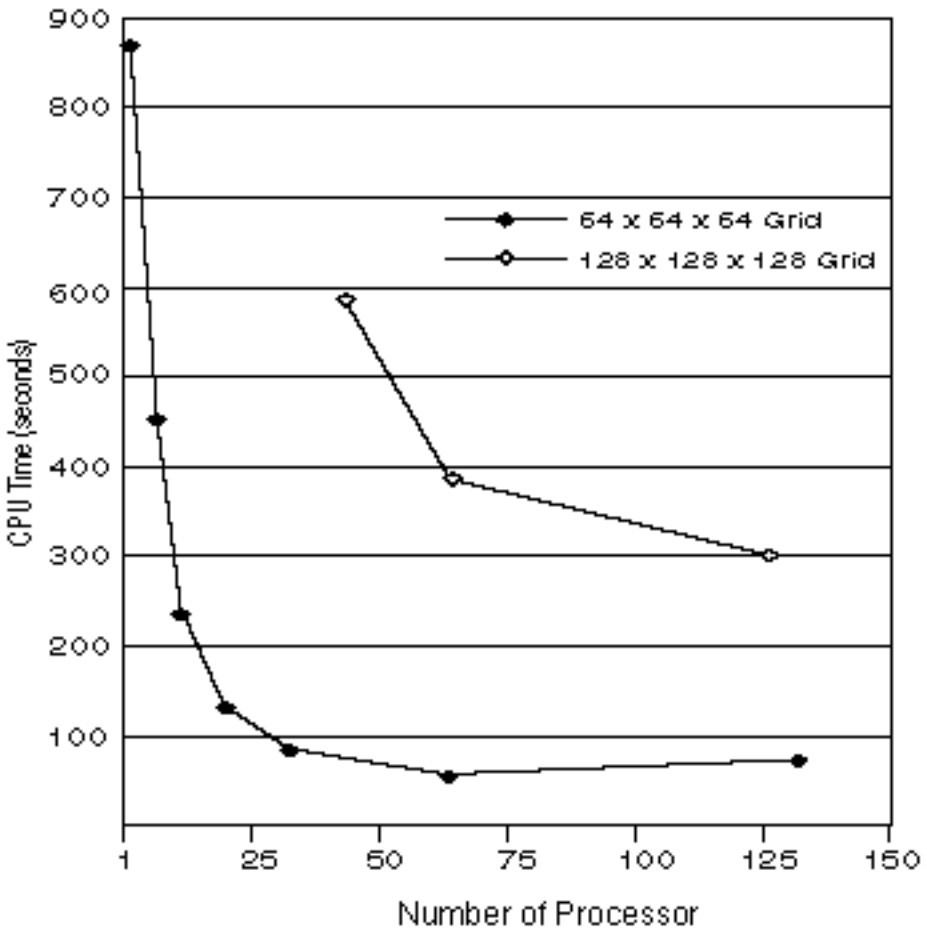

Figure 5. Unscaled Speedup for 3D Multigrid

"Optimization, Fuzzy Adaptive Control, and Intelligent Autonomous Space Exploration"
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Report: Control and optimal decision-making in various industrial, economic, social, and space exploration systems require modeling and analysis techniques that are effective for large, complex, often nonlinear, and imprecisely defined systems. Fuzzy logic, neural networks, and other novel techniques have been successfully used to control complex processes where traditional methods have failed.
Our research objective is the efficient application of fuzzy logic, neural networks, and optimization to autonomous orbital operations at Johnson Space Center (JSC). Through the use of neural networks, reinforcement learning, and dynamic programming (DP) techniques, we will design and test computationally efficient controllers that can learn the correct control actions without a priori information about the system to be controlled. These algorithms will be tested on various high-fidelity simulations of interest to NASA, and the characteristics of the intelligent controller will be investigated fully.

To date we have developed a unique intelligent controller whose learning and control capabilities have been successfully exercised on some standard testbed problems.

Our work has focused on several goals. Initially, we implemented the controller in several computer languages so that it can work on platforms that are compatible with those used by various researchers. Since the controller learns through experience, the choice of language and platform does have a significant impact on the resulting control actions learned.

Extensions to adapt the controller to more general systems have led to the development of a Multiple-Input/Multiple-Output (MIMO) controller. Many control systems have multiple output variables and the control process cannot be readily reduced to independent, parallel, single-output processes.

Finally, we have chosen to apply our controller to two problems of interest to NASA - the tethered satellite system (TSS) retrieval problem, and the control of a four degree-of-freedom robot arm. Although the controller is able to learn some of the characteristics of the optimal control actions in the TSS problem, considerable improvement on its performance is still needed. Modifications to the learning algorithm to improve this performance are currently being investigated.

"Modeling, Control and
Simulation of Semiconductor Growth Processes"
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Date of Original Award: 1992

RESEARCH PROJECT #1:
Process Modeling and Recipe Synthesis for Plasma Enhanced Chemical Vapor Deposition
Report: In integrated circuit fabrication, silicon dioxide films deposited by plasma enhanced chemical vapor deposition (PECVD) are useful as interlayer dielectric for metal-insulator structures such as multichip modules. The PECVD of SiO_2 in a SiH_4/N_2O gas mixture yields films with excellent physical properties. However, due to the complex particle dynamics within a plasma, it is difficult to determine the exact causal nature of the relationship between film properties and controllable deposition conditions. The overall goal of this research was to develop and implement a tool for modeling the PECVD process and recipe synthesis using neural networks and genetic algorithms (guided stochastic search procedures based on natural selection concepts which are used to globally explore multidimensional response surfaces). The procedure called for the deposition of SiO_2 to be characterized via a fractional factorial experiment. Data from this experiment was then used to train feed-forward neural networks using the error back-propagation algorithm. The trained neural networks were then used for recipe synthesis to generate the proper deposition conditions to obtain specific film properties. The response surfaces of the neural process models (Figure 1) were explored using genetic algorithms, the simplex algorithm, Powell's method, and hybrid methods (i.e. - genetic & simplex algorithms, or genetic algorithm & Powell's method). After comparing the performance of these synthesis methods, the optimal techniques were combined with the neural network PECVD modeling system. Deposition was carried out in the Plasma Therm 700 series PECVD system located in the Georgia Tech Microelectronics Research Center. Modeling and synthesis software has been written in C and C++, and resides on a Sun workstation.
RESEARCH PROJECT #2:
Semi-Empirical and Numerical Modeling of Metal-Organic Chemical Vapor Deposition
Report: Metal-organic chemical vapor deposition (MOCVD) has become a very popular technique for growing thin, high-purity epitaxial films with applications in electronics and optics. MOCVD growth is a complex process involving convective and diffusive transport of the reacting species, together with chemical kinetics in the vapor phase and on the solid surface. Numerical modeling of MOCVD reactors

represents a unified theoretical approach to developing insight into the underlying process chemistry and physics.

The goal of this research project was to develop numerical and semi-empirical models for MOCVD growth, with the growth of titanium dioxide films serving as an application vehicle. This work utilized 2- and 3-dimensional numerical simulation and computer visualization techniques to gain a more complete understanding of the fundamental relationships underlying the epitaxial growth process (Figure 2).

To augment the numerical modeling, semi-empirical models utilizing hybrid neural networks were investigated as a means to estimate unknown physical parameters, such as reaction rate constants and activation energies. Back-propagation neural networks have previously been used as "black-box" models of dynamic systems. More recently, hybrid neural nets have been used as process variable estimators in modeling bioreactors. In this project, we have similarly integrated available physical models with neural networks to provide a more robust model of process behavior under a variety of deposition conditions.

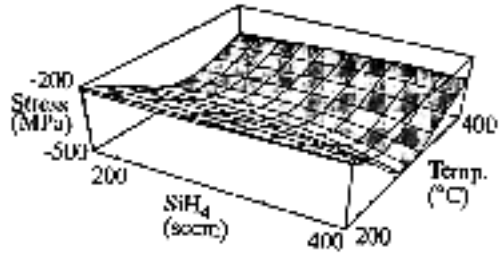

Figure 1. Plot of Residual Stress vs. Silane Flow and Temperature for a PECVD-Deposited SiO2 Film

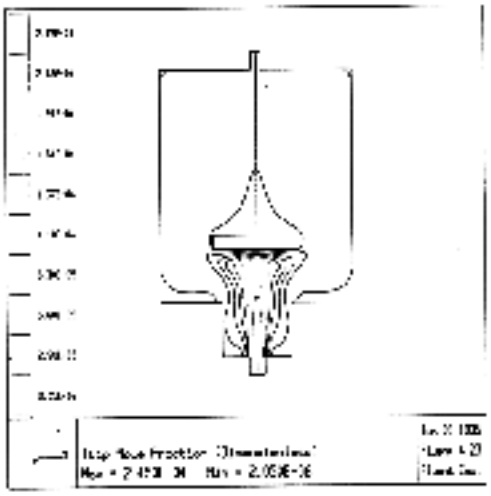

Figure 2. Contour Plot of Precursor Mole Fraction for TiO2 Growth in a Vertical MOCVD Reactor

"Adaptive Phase Alignment of Synthetic Apertures for Coherent Optical Communications"
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Date of Original Award: 1992

Report: Under NASA support, we have been investigating an adaptive phase alignment system, using an aperture array of small photodetectors. The goal is to reduce the power loss on optical-heterodyne communication systems, where the power loss is due to phase incoherence of the optical signal across the aperture surface. This phase incoherence is typically caused by atmospheric turbulence, receiver pointing error, receiver platform instability, and vibrations of optical components. We developed a simulator for the adaptive phase alignment system using BPSK modulation, different aperture array configurations, and different noise levels (leading to correlation between the phase noise samples). The simulations are based on a data rate of 1 GHz and an IF of 16 GHz. Earlier, an aperture array configuration of three photodetectors was used, which was motivated by an experimental hardware set-up. Power loss performance was studied via simulation in terms of noise level and angle-of-arrival of the received signal.

The system's performance, in terms of output power, was studied as a function of both the number and size of the array elements, as well as the angle-of-arrival. Analysis of simulation results shows that the adaptive phase alignment system is very effective in approximating the theoretically optimum performance (coherent-sum) under low-to-moderate noise conditions. The effectiveness of the phase alignment system decreases, relative to the coherent-sum performance, as the noise level increases. Moreover, the effect of the system and received noise is to decrease the correlation between phase noise samples; we characterize this phase noise correlation with a noise correlation factor that is inversely related to the noise level. For high-noise conditions, we found that it is better to operate the array in a non-adaptive mode (full-aperture).

We are currently investigating the BER performance of the adaptive phase alignment system using either BPSK or DPSK modulation schemes as a function of noise level, number and size of array elements, and angle-of-arrival of the received signal. We have found that DPSK performs better than BPSK in terms of Pe vs. SNR only when the aperture signal gain becomes negative.

"High Performance Computing
for the Electromagnetic Modeling & Simulation of Interconnects"
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Date of Original Award: 1992

Report:
NON-UNIFORM TRANSMISSION
LINE SIMULATION
In the real world of electronic packaging, transmission lines are likely to be non-uniform and may include discontinuities such as bends, tapers and transitions; hence, the standard simulation tools for uniform lines can no longer be used to analyze them. During the past year, our group has been involved in the development of analysis and simulation tools for these configurations, using the versatility of the scattering parameter formulation. Using these tools, we can now predict the signal distortion caused by non-uniform transmission line structures with accuracy and efficiency. To our knowledge, no commercial package is able to handle this task except by using convolution techniques which are computationally inefficient.

OPTIMAL TRANSIENT SIMULATION

Presently, a number of methods are available for the simulation of coupled transmission lines that are used to model interconnects. In the past year, we have carried out a systematic comparison of these methods with a view to developing an approach that would be optimal in terms of both accuracy and efficiency. This has led to the development of a transient simulation method based on the difference approximation which has the highly desirable feature that it can be conveniently incorporated in a circuit simulator. This approach not only outperforms the standard scattering parameter method, but is very accurate and computationally efficient as well. Software designers at Cadence Design Systems and Intel have recently implemented this method
in their latest commercial circuit simulator.

"Smart PLC Intelligent Controllers"
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Date of Original Award: 1993

Report: The objective of this work has been to build an intelligent controller with two major capabilities. First, it will have sufficient computational power to control high-bandwidth (100 Hz or higher), Single-Input-Single-Output (SISO) systems and low- bandwidth (10 HZ or lower), Multi-Input-Multi-Output (MIMO) systems. Second, it will have all of the controller's features, even the analog filtering section, purely under computer control.

To date, a complete running version of an intelligent adaptive algorithm, originally developed in Intel-family assembly code, has been successfully ported and demonstrated in Motorola DSP 56K family mixed assembly/C++ code. Numerous simulations and verifications have been run. Due to budgetary problems involved in purchasing the needed development software for the Motorola IDSP family, a switch was made in early 1995 to the Texas Instruments TMS320 DSP family, as software development tools were available at no cost through that company's university support program. At this writing, the algorithm written for the DSP 56K chip has been ported to the TMS320 chip and extensive designs of IXO circuits originally implemented for the DSP 56K chip have been modified for the TMS320 chip and have been implemented in bread-board form. This work is nearing completion and we hope to demonstrate true closed-loop, real-time control soon.

Additionally, a mechanical testbed has been constructed and fully instrumented in the form of a high-bandwidth (100 Hz), inverted pendulum system. A second testbed, a floating-ball apparatus, is under construction.
RESEARCH AREA: MECHANICAL ENGINEERING

"Novel Flow Configuration for the Study of Turbulent Flame Propagation"
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Date of Original Award: 1993

Report:
RESEARCH OBJECTIVES

Premixed flame propagation in turbulent flow is being investigated experimentally using a Taylor-Couette flow reactor (c.f. Figure 1). A fully developed turbulent flow is generated in the annulus between two concentric cylinders rotating in opposite directions. A flame is ignited at the open top end of the apparatus and propagates downward through the annulus. The propagation rate of the flame and its dependence on turbulence intensity and strain rate and on heat loss parameters will be measured and compared with analytical and computational predictions. A TSI Laser Doppler Velocimetry System is used to measure turbulence properties.

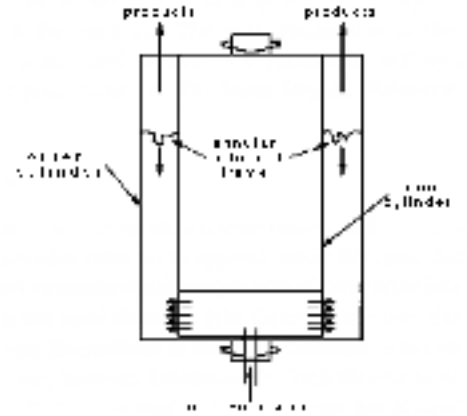

Figure 1. Taylor-Couette Apparatus for Turbulent Premixed-Flame Studies

RESEARCH PROGRESS

The experimental apparatus has been designed and constructed, and measurements of turbulence intensities have been made for cylinder rotation rates up to approximately 800 rpm. Across the annulus gap width the intensities of both the axial and circumferential components of turbulence intensity are found to be relatively constant. Homogeneity along the axial direction (the direction of mean flame propagation) has also been verified. The intensity of velocity fluctuations in the circumferential direction is about twice that of velocity fluctuations in the axial direction, however. Intensities for both directions vary essentially linearly with the average cylinder rotation rate. So far, one student has completed her Master's thesis on this project.

In the next phase of the project flame-speed measurements will be carried out and correlated with the turbulence characteristics of the upstream reactant flow.

"Adaptive Structures and Devices for Space Applications"

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Date of Original award: 1992

Report: Piezoelectric motors are being researched widely because of their potentials for micro/macro positioning in both longitudinal and rotary direction. Piezoelectric motors have advantages over conventional motors since they generate no magnetic field, and are quiet, lightweight, and require less power. Inchworm piezoelectric motors also have the advantage of a stepper motor with the resolution in the nanometer range, which makes them suitable for fine positioning application.

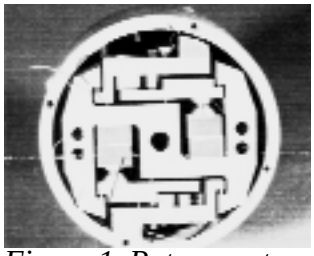

Figure 1. Rotary motor

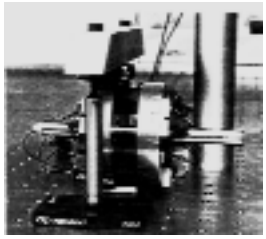

Figure 2. Linear Motor

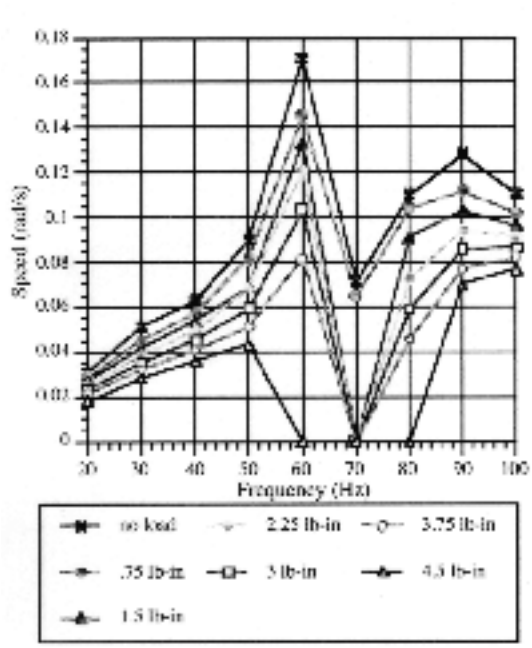

Figure 3. Rotary motor performance

The current research is to design and build both linear and rotary inchworm motors (see Figures 1 and 2) that are capable of delivering high load, speed, and resolution. The motor designs utilize the electromechanical coupling coefficient d33 of the PZT stack to provide both linear and rotary motion. PZT stacks are used as opposed to monolith ones because a PZT stack provides larger displacement at lower input voltage and is safer to operate. Amplified motion of the stacks was used throughout the design by flexure hinges mechanisms. Since the displacement of PZT is in the micrometer range, amplification of this motion is essential to overcome the gaps resulting from tolerances in manufacturing. The rotary motor does not use a torisonal or obliquely poled piezoelectric actuator to provide rotary motion. The rotary motion is achieved by converting the linear displacement of the stack to a curvilinear one through a flexure mechanism. This arrangement allows the stack to indirectly carry the shear load from external torque, thereby increasing the load capability.

The current rotary motor has a static holding torque of 25.5 lb-in using only one clamping mechanism at 200 V input. Maximum rotation of 0.15˚ per step is achieved with 160V input into the rotary section. Resolution of 0.042 mili-arcsecond can be achieved. The linear motor has a maximum velocity of 12mm/s and a static holding force of 4.8Kgf at 400V input. Figure 3 shows the performance of the rotary motor under various torque loading conditions.

"A Supervisory Controlled Telerobotic System"

Principal Investigator: Dr. Gregory L. Long
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Date of Original Award: 1993

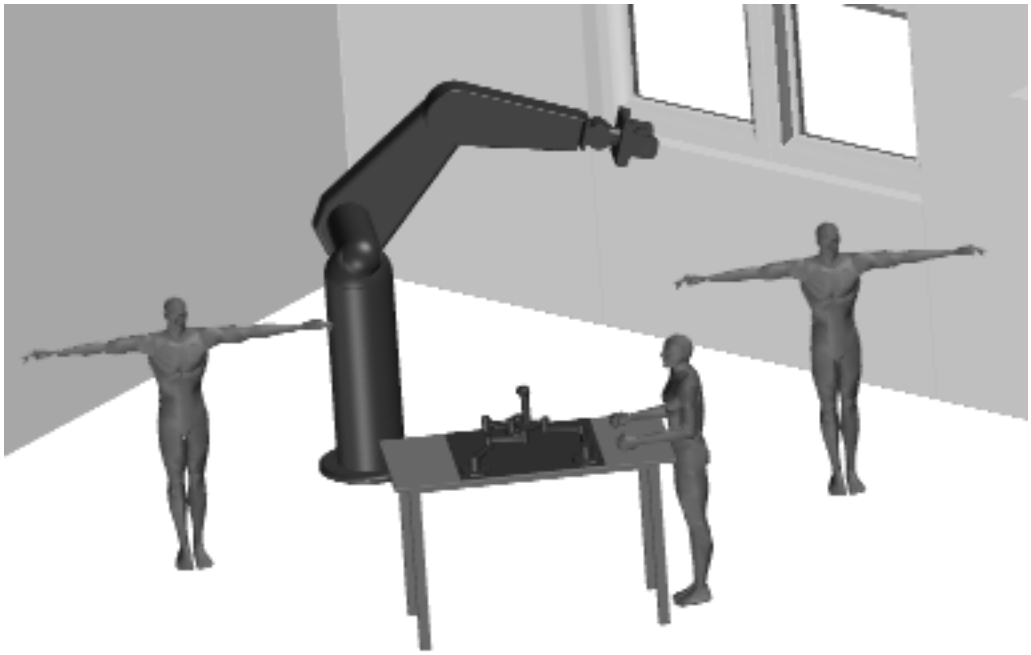
Report:

INTRODUCTION

Ergonomically designed force-reflecting hand controllers (joysticks), coupled to virtual-reality environments, hold great promise for telerobotic interfaces. Human teleoperated systems are primarily intended to provide dexterous motion/force capabilities to a remote manipulator. Demand for these systems range from outer space exploration to environmental clean-up and hazardous waste removal.

RESEARCH OUTCOMES AND PROGRESS TO DATE

Our research objectives for the current review period have been to establish a theoretical framework for the implementation of a redundantly actuated in-parallel force-reflecting hand controller. This system consists of a six degree-of-constraint hand controller and a PUMA robot equipped with a 6-axis force sensor. This prototype system will be used for teleoperation experiments and for testing singularity avoidance and fault tolerant algorithms.



THEORETICAL INVESTIGATIONS
A force-reflecting hand controller with nine actuators has been proposed for force feedback with singularity avoidance. With this new configuration, forces can be exerted at any point in the hand controller's dexterous workspace without actuator saturation. A straight-forward redundancy resolution scheme utilizing a closed-form force distribution solution has been developed. Analytic methods for redundancy resolution have been examined for application to other actuator configurations.

EXPERIMENTAL HARDWARE/
SOFTWARE DEVELOPMENT
The UCI hand controller has been successfully interfaced to a 50MHz 486-based computer. A 6-axis PID control system has been developed and tested in conjunction with the forward and inverse kinematics routines. A digital I/O board has been selected for use with a 6-axis force sensor, and software is currently being developed for a high-speed parallel interface. The original industrial controller (VAL) has been bypassed, and the PUMA robot is currently being interfaced to the hand controller's host computer.

VIRTUAL-REALITY INTERFACE
Our virtual-reality experiments will utilize the software package Superscape, a PC-based application. It incorporates a C-like programming language that gives the user more control of the virtual world.

"Constitutive Modeling
and Testing of Polymer Matrix Composites Incorporating Physical Aging at Elevated Temperatures"
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Report: Advanced polymer matrix composites (PMCs) are desirable for structural materials in diverse applications such as aircraft, civil infrastructure, and biomedical implants because of their improved strength-to-weight and stiffness-to-weight ratios. A possible disadvantage of polymer-based composites is that the physical and mechanical properties of the matrix often change significantly over time due to exposure to elevated temperatures and environmental factors. For design, long term exposure (i.e., aging) of PMCs must be accounted for through constitutive models in order to accurately asses the effects of aging on performance, crack initiation, and remaining life. The ultimate goal is to develop accurate analytical models and accelerated test methods needed to engineer advanced polymer matrix composites to ensure long-term structural integrity over the design lifetime.

One particular aspect of this aging process, physical aging, is considered in this research. Physical aging is a thermoreversible process that causes the polymer matrix to become stiffer and more brittle, and also causes the creep and stress relaxation rates to be reduced. Due to the explicit time dependence of viscoelasticity, creep and recovery tests are a natural choice for studying the time dependent aging process. While a great deal of research has been performed detailing the effects of physical aging on polymers, very little information is available for high temperature PMCs.

A high temperature graphite fiber reinforced thermoplastic composite, IM7/K3B, has been chosen as the material system suitable for this study. In a composite, the two matrix dominated compliance terms associated with time dependent behavior occur in the transverse and shear directions. Layups selected to provide material properties for these two modes are the unidirectional 12-ply and the angle-ply 8-ply for the in-plane transverse and shear respectively. Rectangular test specimens are cut from laminated panels. Strain in the gauge section is measured with high temperature foil strain gauges applied in the center of the specimen. For the12-ply specimens, the average measurement of two back-to-back gauges, aligned longitudinally, is used to compute transverse creep compliance. For the 8-ply specimens, the average measurement in each direction of four gauges, two back-to-back aligned longitudinally and two back-to-back aligned transversely, is used to compute the shear creep compliance.

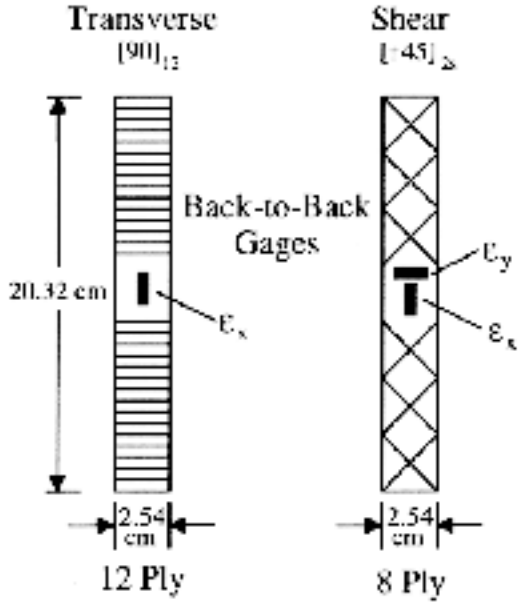

Figure 1. Specimen configuration and gage location for creep compliance tests

RESEARCH AREA: MEDICAL SCIENCES

"Assessing the Putative Mechanism(s) of Gravity-Induced Cellular Changes"
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Abstract: Understanding the underlying cellular mechanism(s) that are responsible for the vascular changes found in animals and humans on space flights is a primary goal of the life sciences program of NASA. Achieving this goal is a necessity for the development of interventions that allow for continued and long-term manned space flights. A step in reaching this overall goal is ground-based studies that investigate the cellular changes, and the molecular mechanism(s) responsible for these changes, induced by altered gravitational fields. Ground-based studies utilizing cultured vascular smooth muscle cells (SMC) will provide the initial insight into possible mechanisms by which the space environment may alter vascular cell growth and behavior.

The specific aims of the proposed research are to: 1) evaluate whether changes in SMC proliferation and migration induced by different gravitational fields are coupled to the expression of autocrine growth and migration factors (e.g., c-myc, TGFB, FGF and galaptin), using antisense oligonucleotides to the mRNA for these substances; 2) assess whether simulated microgravity and/or hypergravity will alter the expression of autocrine growth and migration factors by SMC; and 3) investigate possible signal transduction mechanisms that may be involved in gravity-induced cellular changes. The overall goals of the research proposed are to provide an understanding of the underlying mechanism by which changes in gravity alter cellular behavior and function, and to provide information useful to understanding the impact of microgravity on wound healing.

The proposal plans to support the research training of one undergraduate student.

RESEARCH AREA: METALLURGY AND MATERIALS

"Dielectric Spectroscopy as a Materials Reliability Probe"
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Report: The focus of this project has been on the development of a non-destructive testing (NDT) technique which could be used to detect mechanical, environmental, and electrical degradation in critical components used in NASA's missions. The project emphasizes the combination of spectral and spatial measurements for the detection of cracks in structural components and the development of leakage currents in electronic components. The techniques being used include impedance and dielectric spectroscopy and dc resistivity measurements. The importance of electrical measurements for the detection of microstructural features has only been recently recognized, and many researchers are looking at using them for this purpose. In November 1995, over 100 papers will be presented at the first symposium on electrically based microstructural characterization, for which the P.I. is the main organizer. This symposium will be part of the Materials Research Society Fall Meeting in Boston.

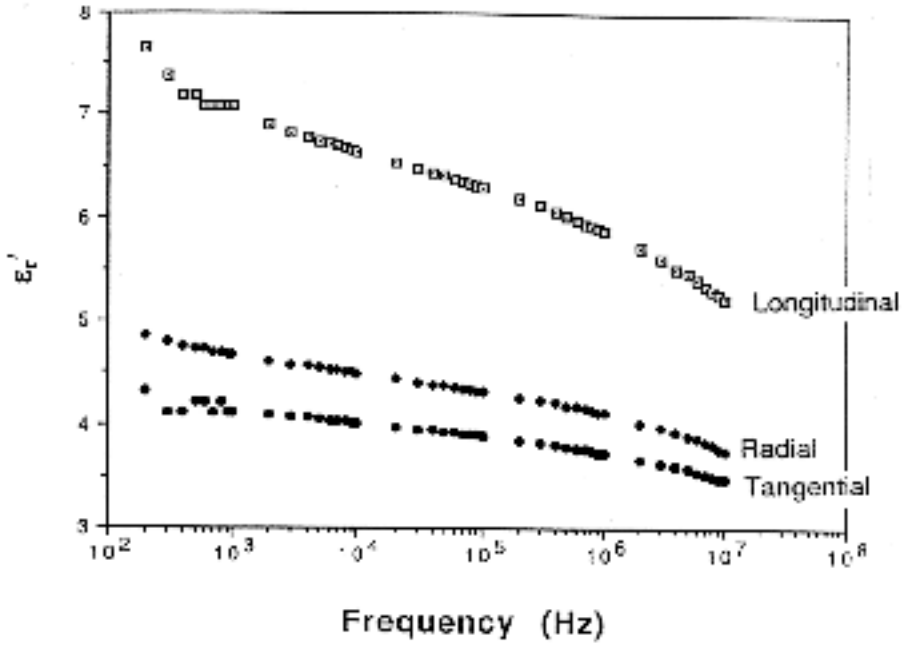

Figure 1.

In order to take advantage of the information provided by the measurements, it is necessary to develop a better understanding of the fundamental changes effected by the microstructural features present in the materials themselves before attempting to carry out in-situ detection of cracks or on-line monitoring of defects and/or leakage paths. Therefore, in the last year we concentrated on evaluating the effect of the orientation of the electric field with respect to the features of interest. Since wood is known to have an anisotropic porous structure, it is an excellent material for establishing the degree to which the measurements are sensitive to the field orientation. Eighteen different wood samples were chosen and were measured with the electric field parallel to the longitudinal, radial, and tangential pores. An example of the difference between the dielectric permittivity for hickory wood along the three directions is depicted in Figure 1. Quantitative stereology measurements of the actual porosity along all three different directions were measured and were found to correspond well with the dielectric measurements. Similar field orientation effects have been detected in a variety of composites containing fibers, whiskers, and dispersoids with different properties from the host.

In addition to these experimental studies, we are also performing numerical calculations for predicting the effective capacitance of a material when a defect is embedded in it. The boundary element method is currently being employed. This is being done in order to establish the best experimental conditions under which the presence of an unknown defect can be detected. Preliminary results indicate that the size and position of the electrodes with respect to the size and position of the defect have a strong influence on whether a defect can be detected or not. It can also be concluded that the higher the dielectric constant of the matrix is, the easier it is to locate a defect. Future calculations will also include finite element modeling.

"Chemically Derived Dense Alumina-Zirconia Composites for Improved Mechanical and Wear Erosion Properties"

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Report: The development of new materials with improved properties such as strength, toughness, and wear resistance for advanced structural applications (such as engine components) will be crucial in meeting emerging high-technology aerospace applications. Zirconia-toughened alumina (ZTA) has the potential to improve toughness and strength when compared to pure alumina.

The main objectives in this project are examining factors such as particle size, particle size distribution, and the nature of the polymorph to determine how they contribute to the toughening mechanisms and strength enhancement in ZTAs. These factors can be modified by the processing techniques used in the fabrication of ZTA ceramics. Our progress to date has included establishing the synthesis for the preparation of high purity ZTAs. In this research program, high-purity starting materials such as aluminum-, zirconium-, and yttrium-metal alkoxides are being used to prepare ZTA. High-purity starting materials will yield ZTA ceramics free of impurities that could migrate to grain boundaries, and either lower strength and toughness or lead to glass formers at these boundaries.

Our initial synthesis to prepare ZTA has been accomplished by using aluminum-tri-secbutoxide, zirconium butoxide, and yttrium butoxide. We synthesized the yttrium butoxide by performing an alcohol exchange of yttrium isopropoxide in butanol. We are now in the process of conducting calcining and sintering studies in the preparation of the ZTA ceramic. Synthesis conditions are being varied and their effect on the final properties of the ZTA will be established.

"Scanning Tunneling Microscopic Studies of Diamond and Optoelectronic Materials"
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Report: Our major research objective is to study the chemical vapor deposition (CVD) diamond growth process using atomic-resolution ultrahigh vacuum (UHV) scanning tunneling microscopy (STM). In particular, we proposed to study the role of atomic hydrogen in the growth process, which is currently not known. An understanding of the CVD diamond growth process will result in the growth of high- quality diamond films that have applications in areas such as protective coatings, cutting instruments and radiation-resistant electronics.

Epitaxial diamond films were grown on natural diamond substrates using CVD. Atomic resolution UHV STM imaging of these films was achieved revealing a (2x1) dimer reconstruction and amorphous atomic regions. The amorphous regions were identified as amorphous carbon. The effects of atomic hydrogen on the amorphous carbon regions were studied in detail. Samples were exposed to atomic hydrogen in the CVD growth chamber and then transferred in situ to the UHV STM chamber without exposing the samples to air. We observed that atomic hydrogen changed the amorphous carbon regions into diamond (2x1) reconstructed regions. This observation is in excellent agreement with a recent model for CVD diamond growth that involves the formation of an amorphous carburized layer on the diamond surface that is converted to diamond by atomic hydrogen. In addition, we studied, using STM, the nucleation and growth of diamond films on Si and highly-oriented-pyrolytic graphite substrates. We are currently studying the CVD diamond growth process in epitaxial diamond and films using UHV STM.

A graduate student and an undergraduate student, who are underrepresented minorities, were supported under this grant. The graduate student, Albert Aviles, received an award at the Fall 1994 Meeting of the Texas Section of the American Physical Society for his paper "Atomic Resolution Scanning Tunneling Microscopy Studies of CVD Diamond Growth."

Publications resulting from this project include:

1. R.E. Stallcup, A. F. Aviles, and J.M. Perez, "Atomic Resolution Ultrahigh Vacuum Scanning Tunneling Microscopy of Epitaxial Diamond (100) Films," Appl. Phys. Lett. 66, 2331 (1995).

2. A.F. Aviles, R.E. Stallcup, W. Rivera, and J.M. Perez, "Scanning Tunneling Microscopy of Chemical Vapor Deposition Diamond Film Growth on Highly-Oriented-Pyrolytic Graphite and Si," Proceedings of the 2nd Atomic Force Microscopy/Scanning Tunneling Microscopy Symposium (Plenum Press, New York, 1995).

"Development of an Ultrasonic
and Fabry-Perot Interferometer System for Nondestructive Inspection of Aging Aircraft Structures"
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Report: In this research, a Fiber-Optic Fabry-Perot Interferometer (FPI) type sensor is being fabricated using single mode optical fibers. Preliminary studies are being performed on thermal, mechanical vibration, and ultrasonic wave responses of these sensors. The focus of this work is to establish a scientific base for a cost-effective, reliable, and portable Fabry-Perot Interferometer and ultrasonic lamb wave dual inspection system for nondestructive detection of flaws in aircraft structures. A Fiber-Optic FPI sensor and ultrasonic lamb wave system will be used to scan aircraft structures for both flawed and unflawed locations, and the experimental results obtained from both techniques will be compared simultaneously.

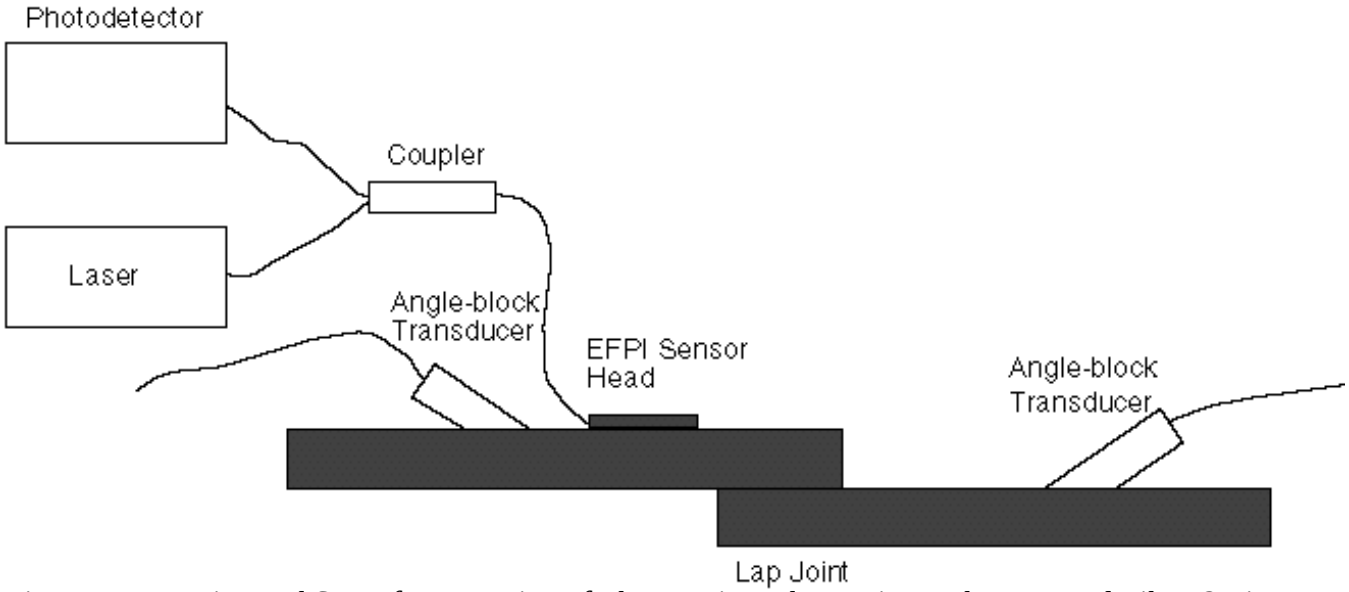

Figure 1. Experimental Setup for Detection of Flaws Using Ultrasonic Lamb Wave and Fiber Optic Sensor

The FPI sensor illustrated in Figure 1 is used in a single mode operation as the inlet and outlet signal. A mirror within the single mode fiber acts as a Fabry-Perot cavity. Light from a laser (1300 nm) is launched into the input arm of a coupler and the other side of the fiber arm is connected to the sensor. The FPI sensor is attached at the top surface of the specimen. The output intensity of the system is detected using a photodetector. The cavity dimension between the two mirrors will undergo changes due to acoustic pressure, caused by the lamb waves. As a result, the change in the cavity dimensions modulates the phase of the light within the cavity, through the strain-optic effect. The modulation, therefore, changes the intensity of light, which is detected using a multimeter. A specially fabricated inspection probe for aircraft structural applications is the key element in this instrument. The probe will incorporate two transducers and an FPI sensor mounted on the aircraft skin.

This instrument will employ two major techniques: the study of the strain-optic effect using a fiber optic FPI sensor, and amplitude measurements using UT lamb waves.

SUMMARY OF PROGRESS
A prototype system has been fabricated and tested in the laboratory to verify the feasibility of the measurements. The first phase of the research is essentially on schedule. I expect to publish the results of this work in a refereed technical journal at the end of this phase of the research.
RESEARCH AREA: OCEANOGRAPHY

"Estimation of Ocean Primary Productivity Using In-situ Fluorescence and SeaWiFS"
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Date of Original Award: 1994

Report: A major goal of optical oceanography in the context of NASA's Mission to Planet Earth is the estimation of phytoplankton primary production in the ocean. Improved measurements of photosynthesis, to be coupled with Earth Observing System (e.g., SeaWiFS) remotely sensed data, are needed for this

task. This study integrates remote sensing of ocean color using the SeaWiFS and in-situ active fluorescence measurements for improved estimation of productivity.
Most estimates of primary production to date from in-situ measurements are based on two methods: changes in concentration of dissolved oxygen in the bulk water, or incorporation of C-14 into particulate matter in bottle incubations. The latter has become synonymous with primary productivity as the method is highly sensitive and amenable for routine use at sea. Controversy has surrounded measurements of photosynthesis based on C-14 incorporation since the method's inception. Inaccuracies in these measurements have been associated with bottle effects, light shock, trace metal toxicity and with partitioning net from gross photosynthesis. In-situ, fluorescence-based measurements of phytoplankton photosynthesis are attractive because they potentially overcome all of these problems.

Fluorescence measurements can be made rapidly, conveniently, and continuously without an incubation, thereby eliminating bottle effects. The measurements reflect gross photosynthetic rates and, because they are practically instantaneous, light shock and trace metal toxicity are negligible. A commercially available version of the Fast Repetition Rate Fluorometer developed by workers at Brookhaven National Laboratory has been ordered to investigate the spatial and temporal variability of fluorescence quantum yield and phytoplankton photosynthesis. Regional primary production will be estimated using spatial distributions of chlorophyll derived from SeaWiFS and rates of photosynthesis measured by fluorescence.

During this first year of the research project, an incubator designed for extensive and sensitive measurements of phytoplankton photosynthetic parameters based on radiolabeled carbon assimilation was constructed and used to develop photosynthesis-irradiance curves. Tests of this device on a cruise conducted to the Eastern Caribbean Sea demonstrated that it allows measurements of carbon fixation in waters with low chlorophyll-a concentration by using a rather large seawater sample. With the capability of simultaneous measurements on 10 water samples, extensive determination of vertical profiles of photosynthetic parameters is achievable.

Due to continued delays in the launching of the SeaWiFS, an alternative means of estimating spatial distributions of chlorophyll-a is being used. In situ measurements, made from a ship, are accomplished using a submersible, active fluorometer. Vertical casts of this instrument were spaced at scales of tens to hundreds of kilometers in the Caribbean Sea. At the present time the tasks at hand include the analysis and interpretation of the fluorometer profiles to develop chlorophyll-a maps, and estimation of photosynthesis rates from radiocarbon experiments to develop estimates of regional production rates.

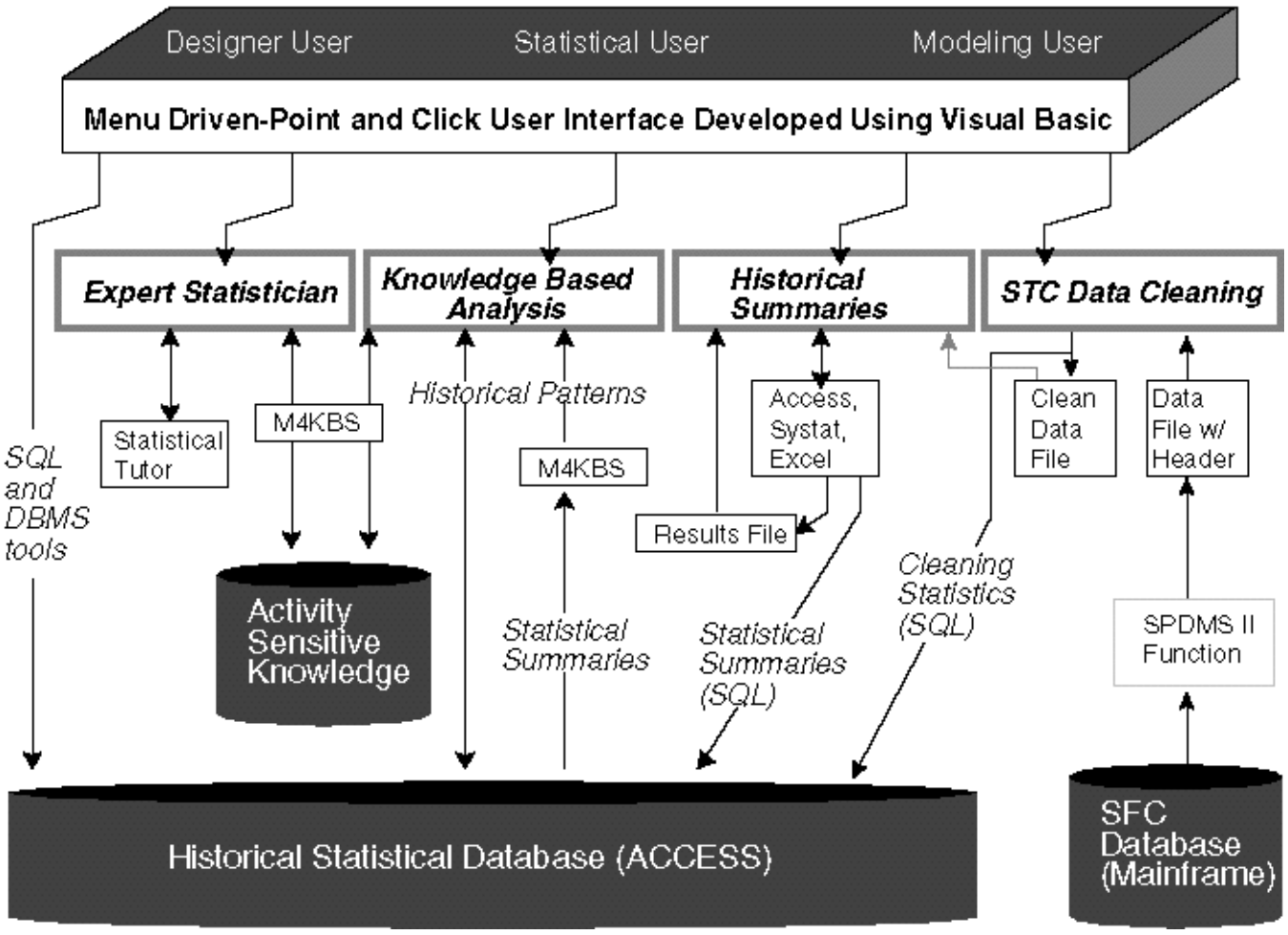

Figure 1. The S.M.A.R.T. Framework

RESEARCH AREA: OTHER ENGINEERING

"Utilization of the SFC Database: A Framework for Modeling Shuttle Processing Operations"
Principal Investigator: Dr. Martha A. Centeno
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Report: The processing of a Space Shuttle requires timely interaction of dozens of technicians and equipment. Delays are natural by-products of this type of complex process, precisely because operations, equipment, and personnel must be integrated across multiple facilities, multiple shifts, and multiple organizations. However, delays may be reduced by improving either the flow of the process, the task schedules, or both. Data regarding Shuttle operations is being stored in the SFC/DC database. It collects information regarding Work Authorization Documents (WAD), including who worked on the WAD, time intervals in which the WAD was being processed or on hold, and why a WAD was placed on hold. Thus, the SFC/DC database contains a vast amount of data that could be utilized to identify areas in need of improvement.

This project seeks to develop a cohesive framework to enable NASA's industrial engineers to effectively use SFC data in establishing, analyzing, and modeling shuttle assembly processes. Specifically, the objectives include:

- Conduct a variety of statistical analyses on SFC data, looking for patterns to benchmark behavior and data integrity problems;
- Evaluate DBMS tools, identify data exchange requirements of various modeling tools, and evaluate development tools such as Visual C++, Visual Basic, and Mozart;
- Review parametric and non-parametric methods to deal with small samples, data reliability uncertainty, and heuristic approaches to include non-quantifiable factors into the analyses;
- Investigate how these methods could be modified so that they can be used in the shuttle environment; and
- Design and prototype the Shop floor Modeling, Analysis and Reporting Tool (SMART), a framework designed around a database (Figure 1) that will contain statistical summaries regarding work time, delay duration, and other relevant inferential and descriptive information. [Centeno and Colucci, 1993]

During the first eight months of this project, we have:

- Set up a data extraction and analysis mechanism to establish SFC data modeling potential;
- Selected Visual Basic as the development tool, with M4, ACCESS, Excel 5.0 and SYSTAT as supporting tools;
- Initiated an in-depth survey of the optimization literature;
- Implemented the framework for data exchange between SFC/DC, Visual Basic, Access and Excel 5.0;
- Began implementation of the SMART historic database and supporting Visual Basic software; and
- Developed a prototype design of a statistical advisor.

"Simulation Based Performance Analysis of a Robotic Testbed Control Architecture"
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Report: Robotic systems are complex structures that possess a myriad of pathways. These pathways give life to robotic systems through the transfer of information among the various subsystems. Integration and interaction of these components allow for the successful design and operation of the robotic system. However, these systems are characterized by control problems, sensory input/output tasks, on-line task

planning and trajectory planning, as well as the noise created through constant communication between subsystems.

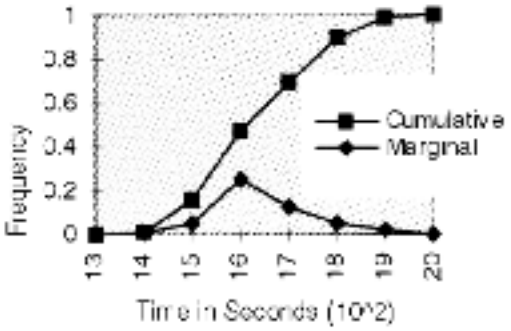

Figure 1. Empirical Distribution Times Required to Complete Assembly of One Strut

The main objective of this project is to apply discrete-event simulation to evaluate the performance of intelligent robotic systems. This work is an extension of a Petri-net based analysis of the robotic testbed at the Center for Intelligent Robotic Systems for Space Exploration (CIRSSE) at Rensselaer. A simulation model of the CIRSSE testbed has been developed using the language ARENA. The performance measure is response time, the expected time required to complete planning and assembly of a truss structure (Figure 1). Times to complete individual system activities are modeled as random variables with means based on the estimated time to complete the activities. Basic models of operator intervention during both direct supervision and telerobotic operation are included. Subsequently detailed algorithms were modeled for robot path planning and error-detection and recovery. The initial step was to graphically animate the simulation model, enabling the analyst to visualize operation of the testbed control architecture. The purpose of this model is to analyze and improve the performance of algorithms for intelligent task planning with respect to the time to complete overall system operation. The model of the robot path planning algorithm considers the mean time to plan feasible paths given the complexity of the environment.

Error detection and recovery procedures are modeled as dependent on the state of the system. Simulation results are presented in terms of a confidence interval on the mean time to complete system operation, and a histogram of observed times to complete operation.

In future research, we will examine three heuristics involved in the planning algorithms in terms of the effect on system response time. For assembly sequence planning, we will evaluate the trade-off between minimizing the distance between successively assembled struts and the number of struts connecting each subassembly. Next, the effect of step size in the local planning portion of the path planning algorithm on system response time will be plotted. Finally, methods for generating alternative intermediate robot positions in the global planning portion of the path planning algorithm will be compared with respect to system response time.

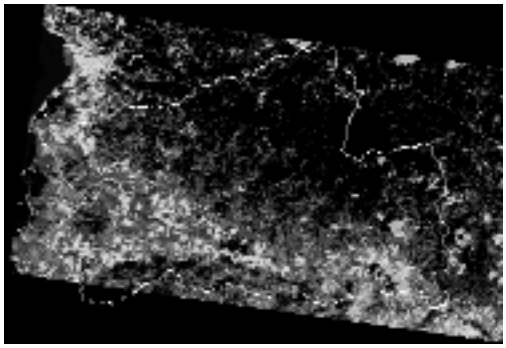

Figure 1. Bands 1, 2, and 3 Composition Over the Guanajibo River Watershed (Mayaguez, P.R.)

OTHER ENVIRONMENTAL SCIENCES

"Land Use Patterns and Fecal Contamination in Coastal Waters of Western Puerto Rico"
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Date of Original Award: 1993

Report: This project is investigating how land use patterns affect the microbiological quality of rivers flowing into Mayaguez Bay in Western Puerto Rico. Coastal shellfish growing areas, bathing beaches, and pristine marine sites in the Bay are affected by the discharge of the three study rivers. Satellite and airborne imagery are being used to study watershed land uses, which serve as nonpoint sources of pathogens affecting coastal water users. The rivers being studied drain watersheds of different sizes and types of human activity (including different human waste treatment and disposal facilities). Land use and land cover in the study river basins are being interpreted and mapped using remotely sensed images from NASA's TM and Calibrated Airborne Multispectral Scanner (CAMS).

The classification is being made combining TM bands 4, 3, and 2 which provide information on water boundaries definition, coastal wetland, and flooded areas, as well as vegetated zones. Using this combination, one may obtain results similar to traditional color IR aerial photography. This creates differences in color of vegetation areas in the image based on reflectance. A red color gradient is used, in which highly vegetated areas appear as dark red and less-vegetated areas appear as light red.

The study will determine whether a significant statistical relationship exists between microbiological water quality in coastal areas and land use patterns in rivers and watersheds that affect them. The study is also using and evaluating current and alternative microbiological water quality indicators that would be of use to regulatory and health agencies dealing with water pollution control. Three different fecal indicators are used in this study (total and fecal coliforms and coliphages) to increase the precision of water quality measurements and to compare results.
Finally, presence of water quality indicators will be correlated with presence of pathogens (water samples will be analyzed for pathogenic bacteria, viruses, and parasites) to determine the usefulness of the different indicators.

Sampling stations	Predominant Land Cover Upstream of Sampling Station	Average Coliphages (pfu/100ml)	Standard deviation of Coliphage density
Station 1: Guanajibo River, Road 102 @ river mouth	urban - agricultural	57.75	102.2
Station 2: Guanajibo River, Road 100 @ upstream	urban - agricultural	26.6	43.3
Station 3: Yagüez River, @ Road 2	urban	378.2	544.3
Station 4: Añasco River, @ Road 2	agricultural	6.9	8.1
Station 5: Composite Coastal Bay Sample	seawater draining all watersheds	0	0
Station 6: Bay Deep Sewage Outfall DiffuserS sample	seawater draining sewer outfall from Mayagüez watersheds	10.1	13.2

Table 1. Preliminary Results for One Water Quality Parameter, Coliphages (n=7)

Table 1 presents average results of water quality analysis for one of the microbiological parameters. Significant differences appear in pathogen indicator densities between the study sampling stations. A photogrametric analysis of images indicates predominant watershed land covers shown in Table 1.

Quantification of land cover areas is currently being carried out using image analysis software (IDRISI package). Figure 1 presents a Landsat TM image of the study area where the Guanajibo river's watershed has been delimited. Further analyses will determine land cover distributions in all study watersheds.

RESEARCH AREA: PHYSICS

"Soft X-ray Optics by Pulsed
Laser Deposition"
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Date of Original Award: 1992

Report: Optical instruments operating at extended ultraviolet (XUV) and soft x-ray (SXR) wavelengths are required in diverse areas such as astronomy, biology, microelectronic circuit fabrication, and laser engineering. Several methods, each with advantages and disadvantages, have been devised to produce optical elements with acceptable performance at these spectral regions. A particularly flexible approach consists of enhancing the reflectivity of surfaces for a given wavelength by depositing a suitably designed multilayer of an appropriately chosen pair of materials. In order to achieve high reflectivity, the individual layers must be extremely thin, and thickness control throughout the structure must be maintained very tightly. Of the thin film growth techniques that have been successfully used to fabricate these multilayers, pulsed laser deposition (PLD) has been the least explored because it is at an earlier stage of development. The main objective of this project is the fabrication and characterization of PLD-grown multilayers in order

to exploit the advantages of and possibly correct some limitations of this technique. Lack of film thickness uniformity due to the narrow forward peaking of the emission plume characteristic of PLD is a problem which has been addressed in this project. A uniformity-enhancing scheme was devised, with two possible approaches for realization. One of these approaches, based on beam scanning over the ablated targets is currently being implemented. If successful, this could lead to PLD-grown large-area multilayer optics.

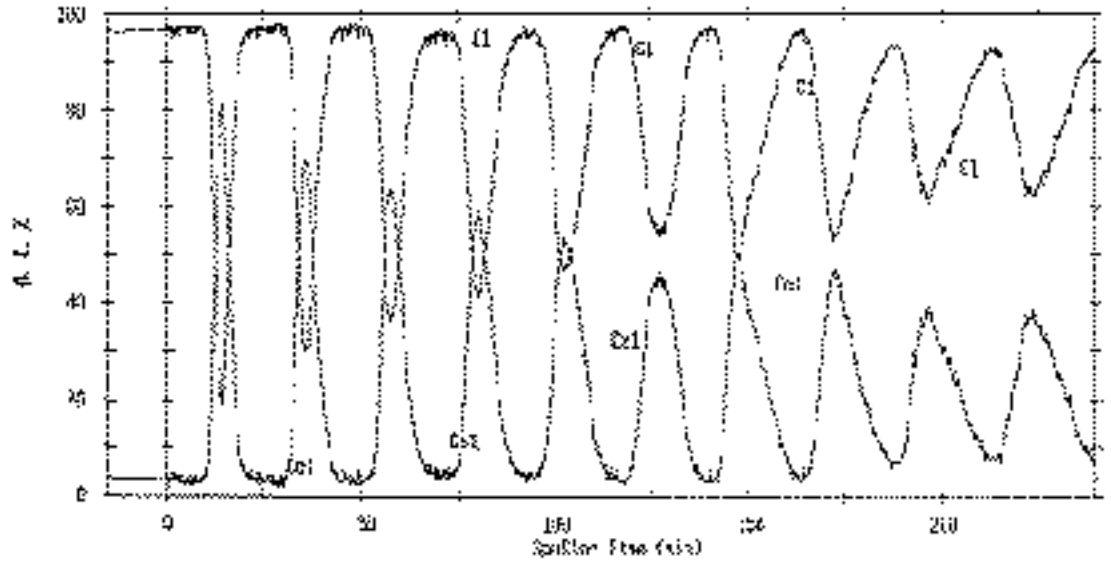

Figure 1. Auger Depth Profile of C/Co multilayer Grown by PLD Showing Percentage Atomic Concentration as a Function of Sputtering Time. The sample is continuously etched by sputtering with an Ar ion beam. The C and Co signals are indicated. For the very thin layers in the sample, the ion beam can damage the layering, which is apparent after the first few (topmost) layers.

Recently, as part of this project, a multilayer reflector for 45.8 A radiation at normal incidence was designed and fabricated. Alternating layers of carbon and cobalt with 13.5 A and 9.5 A thicknesses respectively were required, with a total of a few hundred layers. Growth conditions used ensured sub-monolayer deposition per laser pulse, in order to provide adequate thickness control. The C/Co multilayer samples were studied by means of x-ray diffraction, optical and electron microscopy, and Auger electron spectroscopy. Auger depth profiling of the samples shows very good layering, as evidenced in Figure 1. It is noted that, particularly for such thin layers, the ion beam is expected to mix the materials and destroy the layering. This appears to be the case after the first few layers. More detailed analysis of these multilayers is underway.

"High Tc Bolometer Development"
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Report: Bolometers provide long wavelength detection at low power usage, especially when passive cooling methods can be employed, as in space. The challenge involved with present High-Temperature Coefficient (Tc) technology is in reducing the noise figure as much as possible. Our approach to achieving this goal has taken two distinct tracks.

First, various kinds of thin films have been successfully grown (e.g., YBa2XCu3O7 and CeO2) on MgO and Sapphire substrates. MgO and Sapphire are favored due to their thermal properties. Ultimately, Si substrates will be useful (with YSZ buffer layer) in order to take advantage of developments in Si micromachining. Ag doping has been found to enhance the quality and epitaxial growth of the thin films. Various patterns have resulted, including Bridge and Meander patterns. The films with Ag doping have been found to have large grain size and fewer grain boundaries. The sharp transition in the critical temperature measurement and the small transition width create films having large critical current density, which is required for devices to have improved noise performance, (This work is being performed by an A&T graduate student supported by this grant.)

Second, preliminary work is continuing in the development of a bolometer that operates on the change in magnetic attributes due to incident light. The change in the magnetic field is detected by a squid (the PI is involved in this effort). The effort to set up a bolometer test facility has begun by establishing a facility that is capable of characterizing the electrical properties of superconducting thin films.

"Distributed Bragg
Region Sensors with
Aerospace Applications"
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Date of Original Award: 1994

Report: UV induced holograms in optical fibers have numerous applications in such varied areas as aerospace, telecommunications, and medicine. In the practical application of these structures, it is important that certain standards be established. The following is a brief summary of efforts directed towards this general goal.

The main objective of the funded research effort is the development of distributed sensors and fiber optic centered opto-electronic networks for the intelligent monitoring of phenomena in various structures. In particular, our aim is to fabricate a distributed sensor system using a D-type and other special fibers which can be incorporated into and underneath the surface of structures in order to sense stress, strain, and pressure field variations.

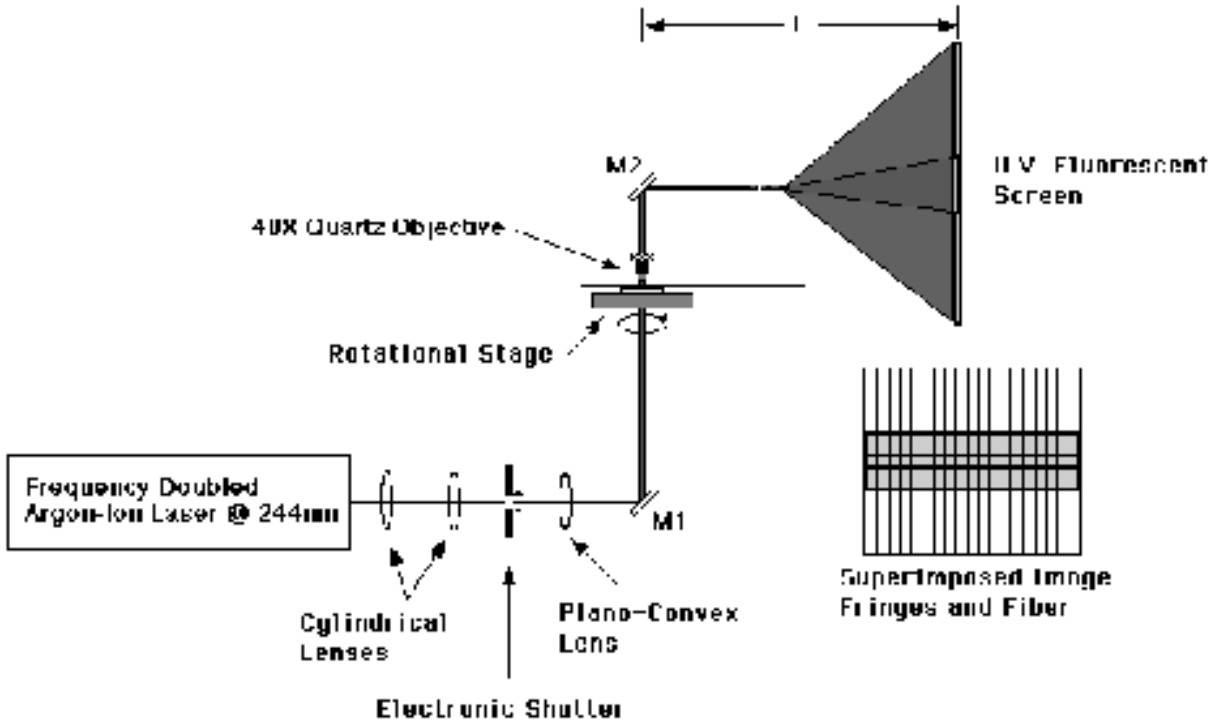

Figure 1. Direct Measurement of UV Fringe Spacings Generated by a Phase Mask Using a 40x Quartz Objective.

To this end, we have built a variable wavelength UV interferometer for writing Bragg filters around the center wavelength 820nm and used various phase masks (one set at 826nm). An example is depicted in the diagram shown in Figure 1.

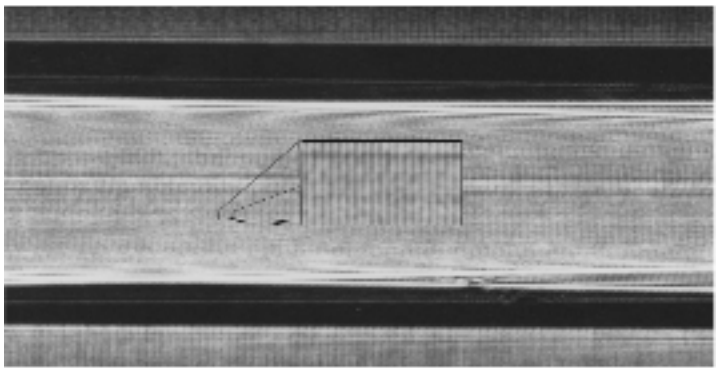

Figure 2. Far Field Projected Image of UV Fringes and D-fiber Using a 40x Quartz Microscope Objective

Additionally, we have been able to verify the interference fringe spacings in D-type fibers using the photographic technique of "grating-fiber image reproduction." These images are shown in Figure 2. This work is a precursor to the establishment of a writing setup that will make a structure utilizing distributed fiber networks truly 'intelligent' by allowing practical numbers of sensors to be placed on a single fiber.

At present, we are still developing readout systems for the verification and characterization of distributed Bragg filters within a given fiber unit.

Currently, there are 2 graduate students, 3 undergraduates, and 3 high school students involved with these experiments.

"Evaluation of Polymer-Dispersed Liquid Crystal Devices"

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Report: The major research objective is to fabricate and evaluate an all-optical interconnect for optical fibers utilizing polymer dispersed liquid crystal (PDLC) technology. The evaluative process includes electro-optical measurements to determine response characteristics and angular dependent light scattering measurements to determine scattering profiles. Ultimately, a liquid crystal and polymer combination that possesses the best response characteristics and scattering profiles will be used to prototype an all-optical interconnect.

Liquid crystal and polymer dispersions, such as PDLC materials, are achieved by polymerization- induced phase separation. Polymerization is initiated in a homogenous mixture of liquid crystal and prepolymer. The low-molecular weight liquid crystal phase separates from the "growing" polymer molecules. The result is a dispersion of micron-sized droplets dispersed throughout the solid polymer. The sample morphology (droplet size, shape, and density) determines the electro-optical and scattering properties of PDLC materials.

Researchers funded by the Canadian Space Agency reported enhancement of electrooptic responses for PDLCs produced in microgravity. The enhancement was attributed to elimination or reduction of the density difference between the low-molecular weight liquid crystal and the polymer during phase separation. One of the missions of the FAR program was fulfilled when the microgravity polymers group at Marshall Space Flight Center provided flight time on their April 1995 parabolic mission to look at polymeric materials. A natural extension of the PDLC activity is to achieve a better understanding of phase separation. This enhanced understanding will further the advancement of PDLC materials.

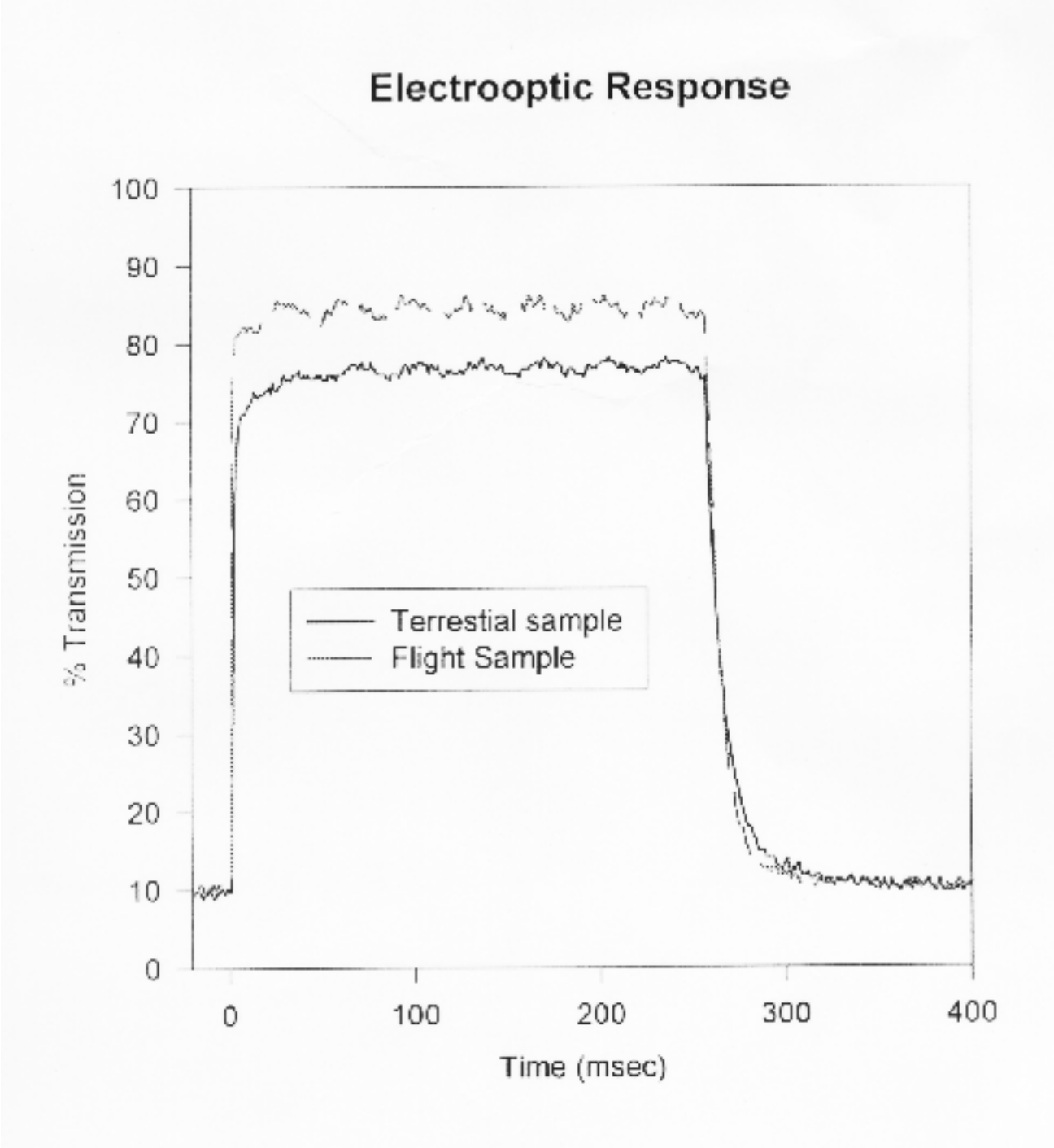

Figure 1. Electro-Optic Response of Sample Pair

Preliminary results indicate differences between samples that are identical to experimental controls except for the gravitational environment during phase separation and the controls themselves. For example, Figure 1 illustrates the electro-optic response of a sample pair, one produced in microgravity (flight) and the other in the laboratory (terrestrial). For this sample pair, approximately 85% of the light is transmitted in the ON-state for the flight sample and 75% is transmitted for the terrestrial sample. At present, Stennis Space Center is performing Scanning Electron Analysis on the PDLC samples in this study. When this

analysis is complete, the sample morphology will be included in the overall analysis to determine what contribution the density difference makes to the phase separation process.

RESEARCH AREA: PLANETARY SCIENCES

"Analysis and Modeling of Venus Gravity and Topography Data from the Magellan Mission"

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Report: The Magellan mission to the planet Venus, which started mapping the surface on September 15, 1990, has already yielded a wealth of new information [Saunders et al., 1992]. After one sampling cycle, the on-board synthetic aperture radar (SAR) had mapped the majority of the planet's surface, with the remainder to be mapped in subsequent cycles extended to 1995. This project is intended to conduct a study of these new data sets in order to better understand the mechanical behavior of Venus' lithosphere, and the dynamics of Venus' mantle as it relates to the lithosphere. The data sets being used in this study include surface topography from altimetry and free-air gravity anomalies.

The on-going research has three major objectives: (1) to obtain values of the admittance (ratio of gravity to topography in the wavenumber domain) for a variety of surface features in order to constrain the apparent depths of compensation (ADCs) for the different features; (2) to analyze the admittance in order to obtain lateral lithospheric strength variations; and (3) to explain the ADCs and the lithospheric strength variations in terms of models of mantle dynamics.

The PI has been assigned a technical supervisor from the Jet Propulsion Laboratory who has been facilitating the electronic data transfer to the PI via the Internet. A number of Fortran files that generate geoid and topography spherical harmonic coefficients have been transferred using ftp, but the transfer of several necessary library subroutines has not been completed due to permission clearance from JPL, which is still being sought.

RESEARCH AREA: SPACE PHYSICS

"Theory of the Motion of Meteor Particles in Solid Materials"

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Report: The penetration of hypervelocity microparticles into a metal target up to the depth of 100 to 10,000 initial diameters of particles has been demonstrated in recent years. This can have important applications for creation of surface-alloyed materials. However, this phenomenon has no reasonable physical explanation and contradicts all existing theories of penetration mechanics.

The main objective of this project is the construction of a theory capable of explaining the super-deep penetration. Such theory is, in main, built in publications funded by the present NASA grant 541803700. The drag of a projectile (particle) moving in a solid material was estimated by means of the invariant Cherepanov integral. (This integral can be used for any constitutive equations of the material in dynamic

regimes.) Various shapes of projectiles and some regimes of their motion were examined. The principal results of these studies are:

1) the drag of wing-shaped projectiles (particles) moving at the Rayleigh speed is several times less than that for lower or higher speeds of the projectiles;

2) the dramatic decrease of drag does not depend on the size of the projectile (i.e., valid for both microparticles and macroprojectiles).

It is evident that these theoretical predictions will have a tremendous impact on future technology if they are examined experimentally and verified.

Four minority graduate students took part in the work of the project (one defended his MS thesis and started work on a Ph.D. thesis in this area; the others are preparing their MS theses).

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